Possible sources for biochar production in the south of the Russian Far East

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Abstract. The study investigates the comparative analysis of biochar from vegetable raw materials and paper. The analysis revealed that biochar from the raw materials we studied showed that biochar has an alkaline reaction of the medium, which means it can be used on acidic soils. The study found that according to the content of nitrogen and phosphorus, the studied material can be used on soils as an organic fertilizer. In general, it can be said that the most effective fertilizer, according to preliminary estimates, will be biochar from *Ahnfeltia tobuchiensis* and a mixture of perennial grasses, due to the high content of nitrogen and phosphorus. The use of biochar from various raw materials sources can become the basis for climate projects and the creation of its own carbon markets in the agricultural sector of the Russian Federation.

1 Introduction

Modern agricultural production is a technological complex that uses the most advanced developments in the field of microbiology, biotechnology, soil science, robotics, etc. According to the latest research by leading European organizations, the urbanization process is actively growing and by 2050 the share of the urban population may reach about 70% [1]. This trend forces agricultural markets to create a new type of ecosystem that unites consumers and producers into complex multi-level systems, where consumer demand becomes the main driving force for the development of a line of ready-made food products. In its report on food security in 2023, the Food and Agriculture Organization of the United Nations (FAO) emphasizes the need for government support for the production of healthy food at affordable prices [1].

The modern agricultural industry in Russia is undergoing huge changes and requires active monetary, resource and personnel injections. The Ministry of Agriculture of the Russian Federation has developed a set of measures aimed at improving the standard of living of rural citizens [2].

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The Far Eastern region is located next to the largest markets for the consumption of agricultural products. Agricultural markets are closely linked to the fertilizer market, and Russia holds a leading position in the export of certain types of mineral fertilizers. The specificity of agro-climatic conditions leads to the search for new technologies to control the water-air regime of the soils of the Primorsky region and create favorable soil conditions for growing agricultural products.

Most of the territory of the Primorsky region's land fund consists of soils of heavy and medium loamy granulometric composition [3], which makes the technology of creating soil structors from natural plant raw materials very popular.

In the Asia-Pacific region, the most common soil structures for regulating the water-air regime of soils are pyrolysis products (biochar) from plant raw materials (rice, coconut, seaweed, wood residues) [4].

In addition to the water-regulating function, biochar is able to reduce the content of heavy metals in the soil, increase fertility and reduce greenhouse gas emissions when selecting an effective dosage, which has been proven by our long-term studies on soils of heavy granulometric composition [5]. In addition to these positive effects, it has been proven that the use of biochar as an agro-soil structurator has a positive effect on the erosion resistance of soils and the formation of an agronomically valuable structure, expressed in an increase in water resistance, aggregation, structurality and other physical parameters of soils. Thus, we can talk about the technology of biochar application as a comprehensive solution to increase fertility and improve water-air properties for soils of heavy granulometric composition formed in monsoon climate conditions.

The implementation of low-carbon technologies into Russian agriculture and the preservation of soil fertility is becoming increasingly relevant, especially given the global demand for decarbonization. The search for solutions in which soil tillage is minimal, and the assimilation of carbon and nitrogen within soil cycles becomes more complete, comes to the fore of modern agroecological applied research. In this regard, it is necessary to create domestic climate projects for Russia's participation in both domestic and foreign agricultural markets.

Most soils in the Far Eastern region are heavy in granulometric composition and during mechanical processing they lose their agronomically valuable structure, due to which there is a loss of soil fertility, including loss of soil carbon and deterioration of the water-air regime [6]. This is especially true for vegetable crops, the yield of which depends not only on the amount of nutrients, but also on their availability to plants due to optimal conditions in the arable soil horizon.

The search for environmentally friendly and inexpensive soil structors, their introduction into agroecosystems, assessment of erosion resistance and greenhouse gas emissions, calculation of the carbon footprint in agricultural production are new research tasks for the introduction of low-carbon technologies in the Far Eastern region.

Despite the fact that biochar is becoming a fairly popular technology in world practice used to improve soil quality and recycle organic waste, the number of publications evaluating the effects of biochar in different soil and climatic conditions remains insufficient [7]. Despite the attractiveness of using biochar as a soil improver and the high efficiency of its use in some experiments, it is important to understand that soil and climatic conditions are the main factors determining both the environmental and economic effects of applying biochar.
The biggest question that arises when evaluating the effectiveness of biochar is the shelf life of this product in the soil [8].

To assess the effectiveness of using biochar as a low-carbon technology, we have established a long-term vegetation field experiment. It was conducted on the territory of the Primorsky Vegetable Experimental Station of the branch of the Federal State Educational

Institution (Surazhevka village, Primorsky region) during the spring and autumn periods of 2018 and 2019 [5, 9].

The greatest sequestration effect was obtained when applying 3 kg/m2 when growing cabbage in a drainage-free area during the first growing season. For a field with an area of 1 hectare sown with cabbage on undrained dark humus beds, under similar climatic conditions and the introduction of woody biochar at a dose of 3 kg/m2 during the growing season (5 months), emissions of approximately 23 tons of CO2 can be reduced. However, it should be taken into account that changing crops, soil and climatic conditions, and the type of biochar can give completely different results, which means that regional adaptation of the technology of carbon deposition into soils using biochar is necessary [5]. Therefore, it is interesting to ask what raw materials can be used in this region other than wood waste? [5].

2 Materials and Methods

The object of the study is a biochar obtained by pyrolysis of various plant raw materials: a mixture of perennial herbs for siderates, coconut fiber, rice husk and two types of algae: *Ahnfeltia tobuchiensis*, *Zostera marina*.

In addition to vegetable raw materials for pyrolysis, used printing paper was taken. Since deep processing of raw materials can become the basis for a climate project, one of the important conditions should be the availability and large amount of waste received. In our study, we also considered used printing paper. This may be a separate climate project for urban infrastructure enterprises.

Pyrolysis was carried out in a vacuum high-temperature furnace Spartherm STZ (China) in an inert medium N_2.

Before pyrolysis, the plant residues were air-dried to a constant weight, then crushed and placed in porcelain crucibles. Pyrolysis conditions for different types of raw materials are presented in Table 1.

Table 1. Pyrolysis conditions for biochar production.

Parameters / Raw material	Pyrolysis temperature, ^oC	Heating time, min.	Pyrolysis time, min.
Used paper	800	30	30
Zostera marina	500	30	30
Ahnfeltia tobuchiensis	500	30	30
Rice husks	500	30	30
Coconut Fiber	500	30	30
A mixture of perennial herbs for siderates	500	30	30

The assessment of the basic parameters of biochar was carried out according to the methodology presented in the recommendations International Biochar Initiative (IBI) [10]. As a result of pyrolysis, the material under study has a different appearance (Figure 1) depending on the feedstock.

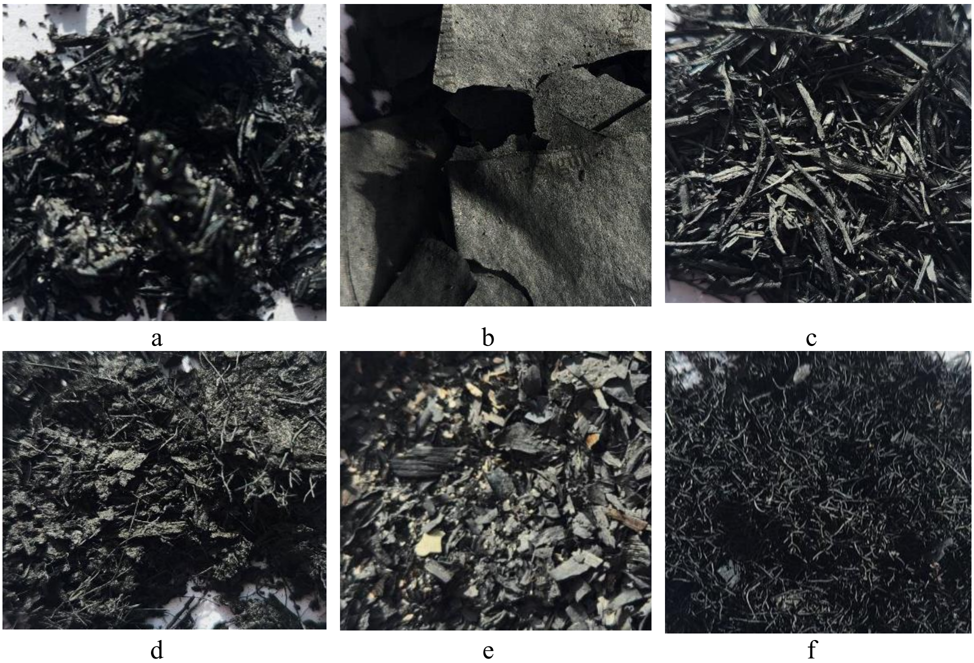

Fig. 1. The appearance of the biochar obtained as a result of pyrolysis of vegetable raw materials and paper.

a - rice husks, b - used paper, c - a mixture of perennial herbs, d - coconut fiber, e - *Zostera marina*, f - *Ahnfeltia tobuchiensis*.

3 Results and Discussion

The main use of biochar will be deposition into the soil, which means that we were interested in the parameters of biochar affecting soil fertility. One of the most important indicators of soil quality is the reaction of the environment. As a rule, biochar is able to shift the reaction of the medium towards the alkaline one. Studies of the acid-base properties of biochar have shown that the reaction of the medium of biochar obtained from *Zostera marina*, *Ahnfeltia tobuchiensis*, rice husk, coconut fiber and siderates is slightly alkaline and values range from 8.91 to 9.67 (Table 2). The reaction of the biochar medium obtained from paper showed a value of 12.17, which refers to a highly alkaline one, which means that such a biochar is well suited for soils with acidic and strongly acidic medium reactions.

Table 2. Basic parameters of the biochar.

Parameters / Raw material	pH	Electrical conductivity, EC, $mS/(m^{-1})$	N, %	P_2O_5, %
Used paper	12.5	9.2	0.2-0.4	not determined
Zostera marina	8.4	12.2	1.8-3.2	0.46
Ahnfeltia tobuchiensis	8.5	13.8	8.2-10.6	0.36
Rice husks	9.3	0.6	1.6-2.3	0.32
Coconut Fiber	9.6	3.3	0.3-0.6	0.19
A mixture of perennial herbs for siderates	9.7	8.0	3.2-3.8	0.81

The electrical conductivity indices in the biochar obtained from *Zostera marina* and *Ahnfeltia tobuchiensis* have values in the range of 12.2 and 13.8 mS/(m-1), respectively. Probably, such high rates are associated with the presence of macro- and microelements in the composition of these plants, which requires additional research. Biochar obtained from rice husks and coconut fiber showed the lowest electrical conductivity values - 0.6 and 3.3 mS/(m-1).

If we talk about such basic elements as phosphorus and nitrogen and their available forms for plants, then according to our research, the most promising are biochars obtained from a mixture of perennial grasses P - 0.8%, N – 2.1- 3.8%; *Ahnfeltia tobuchiensis* P - 0.8%, N – 8-10%, rice husk, cedar husk. As expected, no available phosphorus was found in the biochar made of paper.

The indicators of total nitrogen in biochar vary greatly depending on the feedstock. The lowest nitrogen content is observed in biochar from paper from 0.2 to 0.4% (Table 2). The highest value is in the biochar from *Ahnfeltia tobuchiensis*, in which the total nitrogen content varies from 8.2 to 10.6%.

Thus, the analysis of biochar from the raw materials we studied showed that biochar has an alkaline reaction of the medium, which means it can be used on acidic soils. Also, according to the content of nitrogen and phosphorus, the studied material can be used on soils as an organic fertilizer. In general, it can be said that the most effective fertilizer, according to preliminary estimates, will be biochar from *Ahnfeltia tobuchiensis* and a mixture of perennial grasses, due to the high content of nitrogen and phosphorus.

4 Conclusions

In 2023, Verra released VM0044 Methodology for Biochar Usage in Soil and Non-Soil Applications, version v1.0, which outlines procedures for quantifying the reduction of greenhouse gas (GHG) emissions from the production of biochar and its use in approved soil and non-soil applications [11]. According to the 2019 Special Report of the Intergovernmental Panel on Climate Change, biochar could provide mitigation potential of 1 Gt CO_2 per year by 2050 (conservative estimate) [11].

Thus, we see that the use of biochar from various raw materials sources can become the basis for climate projects and the creation of own carbon markets in the agricultural sector of the Russian Federation.

For the Far Eastern region, we can use seaweed and mown perennial grasses as promising raw materials. Rice husks can also become a promising source for obtaining biochar, as this crop is actively grown in the Far Eastern region.

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