Seeds on a parachute: the technology of greening

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Abstract. To strengthen the sides of tailing dams and stockpiles, it growing forests from trees, shrubs and plant grass. Due to the difficult topography of the terrain, greening technologies require new ideas and material support. The objective of the research is to develop a technology for sowing large areas of plants with seeds from the air. In order to sow large areas with plants, it proposed to scatter seeds (grains) from a height onto hard-to-reach slopes, attached to a parachute system of a special design. Thousands of swarms of miniature capsules with seeds lifted by the drone and released by it at a given height will be scattered by the wind over large cultivated areas. The capsule filled with grain, fertilizer, humus and a compartment with water (gel). The parachute system is a three-dimensional paper platform that allows the capsule attached to it to fall smoothly and slowly. The hooked plumage of the platform provides its reliable grip on the ground. The platform is also soaked with seed nutrients before launch. Analytical, computational and experimental studies have confirmed the highly efficient aerodynamic properties of the developed parachute systems. 3D flying platforms demonstrated controlled rotation kinematics (18 rad/s) and low final speeds of 1.6-1.9 m/s.

1. Introduction
To strengthen the sides of tailing dams and stockpiles, it growing forests from trees, shrubs and plant grass. Forests regulate and retard surface runoff, and prevent the washing away of soil growing on the slopes. It prevent the formation of landslides. Not least is the protection of cities from dust. Not only tailings are gathering dust, but also dams and access roads. All this requires a universal landscaping technology.

Due to the difficult topography of the terrain in Kryvyi Rih iron ore basin, the process of greening is especially laborious. It is extremely difficult to tie together an aggressive and hard environment with tender green sprouts. In addition, an average of 55 mm of precipitation per month falls in the Kryvyi Rih region, which is clearly not enough for the successful germination and further stable development of the plant sprout.

The stockpiles are planted with greenery using different technologies at Kryvyi Rih mining and processing plants. For example, a special cultural liquid was used for the reclamation of the dump slopes at Ingulets GZK [1]. Using hydraulic monitors, a mixture of rapeseeds, cereals and useful substances (nitrogen, potassium, phosphorus, organic polymers) is applied to the dumps. At the end of 2020, the technology was already applied on a plot of more than fifty hectares. As reported, plants sprouted all over the surface. Although it is clear that it is impossible to cover the surface of the slopes with this method. How much the landscaping of one square meter of the slope costs is also not reported, but, obviously, this is an expensive technology.
The slopes of the Northern GZK tailing dump covered with silt, moistened, sown with herbaceous plants to reduce dusting [2]. It is clear that it is also not realistic to process all dusty surfaces in this way. The same gloomy picture is observed at other mining and processing plants.

Therefore, the goal of our research is to develop a technology for sowing plants with seeds over large areas, using a natural assistant - the wind and modern technology - drones.

2. Analysis of actual research
Irish company BioCarbon Engineering uses drone to restore mangrove forest in Myanmar [3]. Figure 1 shows the technology of planting capsules with plants.

![Figure 1. UAV-assisted forest planting technology.](image)

As you can see, the capsules fall on the loosened soil. Watering is carried out after planting the seeds, that is, the exact coordinates of the capsules are required, the processing of a large array of data, and so on. It is difficult to apply this technology to rocks on slopes, although it is progressive in itself. Currently, the drone developed by the company can carry 150 seed capsules at a time.

Drones from the American company DroneSeed shoot seeds into the ground at a speed of 800 seeds per hour [4].

AirSeed Technologies plants up to 40,000 tree seedlings a day [5]. The unique advantages boost the growth rates of developing seedlings by delivering necessary elements directly to the root systems of the germinated seeds. The data collected is used to drive accurate flight plans that not only fly the drones, but also trigger the carbon seed pod and carbon pellet delivery systems at predefined GPS coordinates.

Thus, drone-landscaping technologies are evolving.

3. Object and methods of research
The object of our research is the development of a technology for sowing a mining surface with plant seeds using wind and drones. The work is theoretical and applied. Methodologically, the research based on the well-known laws of mechanics, aerodynamics and conservation of energy.
Its main scientific and practical results obtained with the use of video and photo recording, digital technologies for processing the results of numerous experiments.

In order to sow large areas with grain and grass crops, it proposed to scatter seeds (grains) from a height onto hard-to-reach slopes, attached to a parachute system of a special design. Thousands of swarms of miniature capsules with seeds lifted by the drone and released by it at a given height will be scattered by the wind over large cultivated areas.

Also, miniature wireless electronic sensor devices can be let out together with a swarm of seeds on the same parachute systems, which will create a system for monitoring the environment and tracking the growth of trees and shrubs [6].

4. Results

The shape of the flying platform was determined by us based on the analysis of the results of works devoted to the creation of large swarms of miniature wireless electronic devices [7, 8] for environmental monitoring [9], population monitoring [10], registration of the presence of diseases in the crowd [11] and other applications requiring coverage of large areas. In addition, the results of works studying the scattering of seeds by wind [12], as well as modern methods of mechanical assembly of three-dimensional structures [13–15], were studied. The optimal design of a 3D flying platform is shown in figure 2.

The capsule in the center of the platform is filled with grain, fertilizer, humus and a compartment with water (gel). The parachute system is a three-dimensional paper platform that provides the capsule attached to it with a smooth, slow fall due to wings optimized for this purpose. It is the long fall time of the platform that provides a large spread of seeds released by the drone in one place and picked up by the wind. The hooked plumage of the platform provides its reliable grip on the ground. The platform is also soaked with seed nutrients before launch. Instead of a paper platform, other environmental materials that have the property of absorbing moisture from the air (moisture-retaining substances) can also be used. The dimensions of the parachute system correlate with the size and weight of the transported seeds.

The average annual wind speed at a height of 10 meters in the Kryvyi Rih basin is 4.2 m/s. As you know, wind speed increases with height according to a power law. The exponent $k$ is
determined by the structure of the underlying surface. For cities with tall buildings $k \approx 0.4$. Obviously, for a sown mountainous area, the exponent of $k$ will be of the same order. Therefore, in our calculations, $k = 0.4$ and the dependence of the speed on the wind was taken equal to:

$$v_1 = v_0 \cdot (H_1/H_0)^{0.4},$$

$v_0 = 4.2$ m/s - wind velocity at height $H_0 = 10$ m above the earth’s surface.

The final choice of the design of the flying platform shown in figure 2 is due to preliminary optimization of parachute system parameters. For this purpose, an analytical model was developed for three-dimensional falling aircraft with rotation, and their aerodynamic behavior was considered. The final vertical velocity $v_{\text{max}}$ and the angular velocity $\omega_{\text{max}}$ were chosen as the key parameters that describe the behavior of aircraft during a fall in a stable flight state. They significantly depend both on the properties of the air (air density $\rho$, dynamic viscosity $\mu$, etc.) and platform geometry (three-dimensional configuration, tilt angle, their number, area, and so on). The rotation velocity of the platform is proportional to the ratio of the final fall velocity to the radius of the platform. Thus, the maximum vertical fall velocity of the platform is decisive in the calculations. The performed calculations showed that the maximum vertical velocity of the platform fall is determined by the formula:

$$v_{\text{max}} = \left[ \frac{2}{\rho G} \left( \rho_{\text{mat}} gd \right) \sqrt{\eta} + \frac{P}{\pi r^2 \sqrt{\eta}} \right]^{1/2},$$

where $\rho$ - the air density, $G$ - the coefficient that takes into account the drag and lift force of a rotating blade aerodynamic profile, $d$ - the blade thickness, $\eta$ - the platform area fill factor, $P$ - the seed weight.

In situ experiments were carried out to determine the actual vertical velocity $v_2$ of winged platforms fall. The vertical velocity of 3D platforms in our experiments was the value $v_2 = 1.6 - 1.9$ m/s, which is safe for seeds. The relations between the weight of the cargo $P$ [mN] with the platform and the final velocity of the falling platform $\varnothing 40$ mm was determined by empirical formula (figure 3):

$$v = -0.3P^2 + 1.36P + 0.17, [m/s]$$

The influence of the porosity of the platform material on the final velocity of its fall was also studied. The advantage of porous materials is a significant reduction in the weight of the platform. As it turned out in experiments, the limiting rate of fall decreases $k$ times with increasing porosity $p$ according to a linear law:

$$k = \frac{p}{3}.$$
Figure 3. The relations between the weight of the cargo $P$ [mN] with the platform and the final velocity of the falling platform $\varnothing 40$ mm.

The mass of the seed, the mass of the flying platform, the number of grains per one $m^2$. So, with a load capacity of 5 kg, a grain mass of 40mg, a coverage grid - a square with a side of 1m, the coverage radius will be 300 m. The height of seed discharge without a platform in this case is 60 meters. When placing seeds in a grid with a side of 0.5 m, the coverage radius will be 150m and the seeds must be dropped from a height of 40 meters.

Thus, the criteria for the successful operation of a sowing drone are defined. The technology of greening includes five stages:

Figure 4. The dependence of the covered area radius on the height of the seed discharge: blue color – $v=1.6$ m/s, red color – $v=1.9$ m/s.
1. Creation of a 3-D map of the area by photographing areas subject to reclamation with drone cameras.

2. After analyzing the topography of the terrain data, creating a seeding plan that best fits the landscape.

3. Drones are equipped with tubes that contain flying platforms with capsules that include germinated seeds and hydrogel.

4. Drones fly at a calculated height above the ground. Following the landing pattern, they release biodegradable seed capsules over the slope, located on flying platforms.

5. After planting the seed, the drones perform low-level flights, photographing seedlings to assess the health of shoots and seedlings.

5. Conclusions

Thus, the main result of the study is evidence that the combination of drones with miniature parachute three-dimensional (3D) systems provides a solution to an important environmental problem, namely, sowing the slopes of tailing dams and stockpiles with plant seeds.

The main parameters for the optimal distribution of seed capsules under the effect of wind was determined. The designs of load-bearing platforms was studied, their shape was determined, which ensures controlled flight in the natural environment. Analytical, computational and experimental studies have confirmed the highly efficient aerodynamic properties of the developed parachute systems. 3D flying platforms demonstrated controlled rotation kinematics (18 rad/s) and low final speeds of 1.6-1.9 m/s. The aim of the work achieved using the proposed concept of gardening hard-to-reach places using drones, wind, and microcapsules with seeds on a flying 3D platform.

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References

[1] 1krua 2020 Dumps are planted at InguletskyGZK using hydromonitors URL https://1kr.ua/news-61455.html

[2] Skorokhod I 2021 Environmental inspection at SevGOK in Kryvyi Rih URL https://tinyurl.com/y59w6a2e

[3] Biocarbonengineering 2021 Drones plant one billion trees a year URL https://atlasofthefuture.org/project/biocarbon-engineering/

[4] Prentice A E 2021 Droneseed, making reforestation scalable with heavy lift drone swarms School of Architecture Lectures Series vol 239 URL https://surface.syr.edu/architecture_lectures/239

[5] Crumley B 2022 Airseed technologies works to plant 100 million trees by drones URL https://dronedj.com/2022/01/07/airseed-technologies-works-to-plant-100-million-trees-by-drones/

[6] Kim B H, Li K, Kim J, Park Y, Jang H, Wang X, Xie Z, Won S, Mand Yoon H, Lee G, Jang W J, Lee K H, Chung T S, Jung Y H, Heo S Y, Lee Y, Kim J, T C, Kim Y, Prasopsukh P, Yu Y, Yu X, Avila R, Luan H, Song H, Zhu F, Zhao Y, Chen L, Han S H, Kim J, Oh S J, Heon L, Chi H L, Huang Y, Chamorro L P, Zhang Y and Rogers J A 2021 Nature 597 503–510 URL https://www.nature.com/articles/s41586-021-03847-y

[7] Chung H U, Kim B H, Lee J Y, Lee J, Xie Z, Ibler E M, Lee K, Banks A, Jeong J Y, Kim J, Ogle C, Grande D, Yu Y, Jang H, Assen P, Ryu D, Kwak J W, Namkooong M, Park J B, Lee Y, Kim D H, Ryu A, Jeong J, You K, Ji B, Liu Z, Huo Q, Feng X, Deng Y, Xu Y, Jang K I, Kim J, Zhang Y, Ghaffari R, Rand C M, Schau M, Hamvas A, Weese-Mayer D E, Huang Y, Lee S M, Lee C H, Shanbhag N R, Paller A S, Xu S and Rogers J A 2019 Science 363 eaau0780 URL https://www.science.org/doi/10.1126/science.aau0780

[8] Kim B, Liu F, Yu Y, Jang H, Xie Z, Li K, Lee J, Jeong J, Ryu A, Lee Y, Kim D, Wang X, Lee K, Lee J, Won S, Oh N, Kim J, Kim J, Jeong S J, Jang K I, Lee S, Huang Y, Zhang Y and Rogers J 2018 Advanced Functional Materials 28 1–10 URL http://hdl.handle.net/20.500.11750/9324
[9] Jin J, Wang Y, Jiang H and Chen X 2018 *Scientific Reports* **8** 1–9 URL https://www.researchgate.net/publication/328770471_Evaluation_of_Microclimatic_Detection_by_a_Wireless_Sensor_Network_in_Forest_Ecosystems

[10] González-Alcaide G, Llorente P and Ramos-Rincón J M 2020 *Heliyon* **6** E05141 URL https://doi.org/10.1016/j.heliyon.2020.e05141

[11] Groseclose S L and Buckeridge D L 2017 *Annual Review of Public Health* **38** 57–79 URL https://www.annualreviews.org/doi/10.1146/annurev-publhealth-031816-044348

[12] Augspurger C K 1986 *American Journal of Botany* **73** 353–363 URL https://doi.org/10.1002/j.1537-2197.1986.tb12048.x

[13] Won S M, Wang H, Kim B H, Lee K H, Jang H, Kwon K, Han M, Crawford K E, Li H, Lee Y, Yuan X, Kim S B, Oh Y S, Jang W J, Lee J Y, Han S, Kim J, Wang X, Xie Z, Zhang Y, Huang Y and Rogers J A 2019 *ACS Nano* **13** 10972–10979 URL https://doi.org/10.1021/acsnano.9b02030

[14] Kim B H, Lee J, Won S M, Xie Z, Chang J K, Yu Y, Cho Y K, Jang H, Jeong J Y, Lee Y, Ryu A, Kim D H, Lee K H, Lee J Y, Liu F, Wang X, Huo Q, Min S, Wu D, Ji B, Banks A, Kim J, Oh N, Jin H M, Han S, Kang D, Lee C H, Song Y M, Zhang Y, Huang Y, Jang K I and Rogers J A 2018 *ACS Nano* **12** 4164–4171 URL https://pubs.acs.org/doi/10.1021/acsnano.8b00180

[15] Park Y, Franz C K, Ryu H, Luan H, Cotton K Y, Kim J U, Chung T S, Zhao S, Vazquez-Guardado A, Yang D S, Li K, Avila R, Phillips J K, Quezada M J, Jang H, Kwak S S, Won S M, Kwon K, Jeong H, Bandodkar A J, Han M, Zhao H, Osher G R, Wang H, Lee K, Zhang Y, Huang Y, Finan J D and Rogers J A 2021 *Science Advances* **7** eabf9153 URL https://www.science.org/doi/10.1126/sciadv.abf9153