POSSIBLE USE OF PILOTLESS AIRCRAFTS FOR OPERATIVE MONITORING OF THE SOIL PRODUCTIVITY

I. Yu. Savin, Yu. I. Vernyuk, I. Faraslis

[1]*V.V. Dokuchaev Soil Science Institute, 119017 Moscow, Pyzhevskii 7, bld.2*
e-mail: savigory@gmail.com

[2]*Aristotle University of Thessaloniki, University Campus, 54124 Thessaloniki, Greece*

Based upon a comprehensive review of literature sources it seemed reasonable to show that the today's level of technical development and its simplicity allow considering pilotless aircrafts as a reliable tool for operative monitoring of soils and crops on fields and areas of small farms. The possible use of the imagery obtained by pilotless aircrafts is predetermined by a type of survey apparatus to a considerable extent. At present, the miniature survey apparatus permits to obtain images, the spectral resolution of which may be compatible with those obtained by satellites. Today, the images of pilotless aircrafts are used to give a visual assessment of any object to be surveyed. However, there are publications devoted to computer analysis of images obtained for agricultural purposes. The experience is becoming common to use the data of pilotless aircrafts and their computer analysis for creating digital models of the field relief, monitoring over the soil erodibility and operative valuation of the state of agricultural crops. Being compared with satellite imagery, the data of pilotless aircrafts have a number of advantages in aerial surveying. The shortcoming consists only in insufficient miniaturization of surveying apparatus and impossible monitoring of large areas.

Keywords: pilotless aircrafts, remote sensing techniques, soil interpretation, state of crops.

One of the trends in the Program of fundamental investigations adopted by the V.V. Dokuchaev Soil Science Institute and Russian Institute of Agricultural Microbiology and included into a set of programs approved by the Presidium of Russian Academy of Sciences (decision No. 10115-54 on February 03, 2015) is the elaboration of methods for digital remote inventory and monitoring of the arable soils and lands in Russia.

The use of remote sensing techniques for inventory and monitoring of soils and lands in the country has a long history. 90 years ago it began with pioneering work of several researchers engaged in using the data of aerial survey for purposes of agriculture [11, 16, 18]. Later on, the satellite information has been used [1, 2, 9, 17, 14, 15, 19]. At the current stage of the development the attempts are made to implement the automated interpretation of the obtained data [8, 6, 10, 12, 13,]. Over this period a great experience has being gained in sounding of soils and crops with the help of the materials obtained by remote sensing techniques. In comparison to the terrestrial survey, the advantage of remote methods is beyond doubt now.

Although the task related to elaborating the automated systems of monitoring over soils and crops by satellite survey is of great practical importance it has been so far solved incompletely. This is explained by a level of technical development, high expenses as well as the effect of clouds on remote data to obtain them in the moment when they are urgently required.

By today, the pilotless aircrafts are widely adopted in different spheres of national economy including the agriculture. Their use is cheap to a considerable extent and technically modified to give a visual assessment of any observation object. This is testified by publications devoted to the possible computer analysis of imaginary obtained by pilotless aircrafts [4, 20–23].

One of the prospecting trends in using the pilotless aircrafts is constructing digital models of relief to evaluate the land suitability, planning of the land use and modeling of processes causing the changes in soils and their functions.

Fig. 1 demonstrates an example of 3D imagination of the territory surveyed by the pilotless aircraft near Volos town in Greece.

The main problem of using these data for the computer analysis of relief consists in that the survey by pilotless aircrafts allows creating the digital model of the territory but not the relief. All the terrestrial objects such as trees, buildings, embankments, etc. in this model hamper the angles calculation of slope inclination and exposition. There are no efficient methods to avoid the influence of these objects in order to create a digital model of relief. It is worthy of note that this problem cannot be arisen in case of obtaining the data about relief within the fields occupied

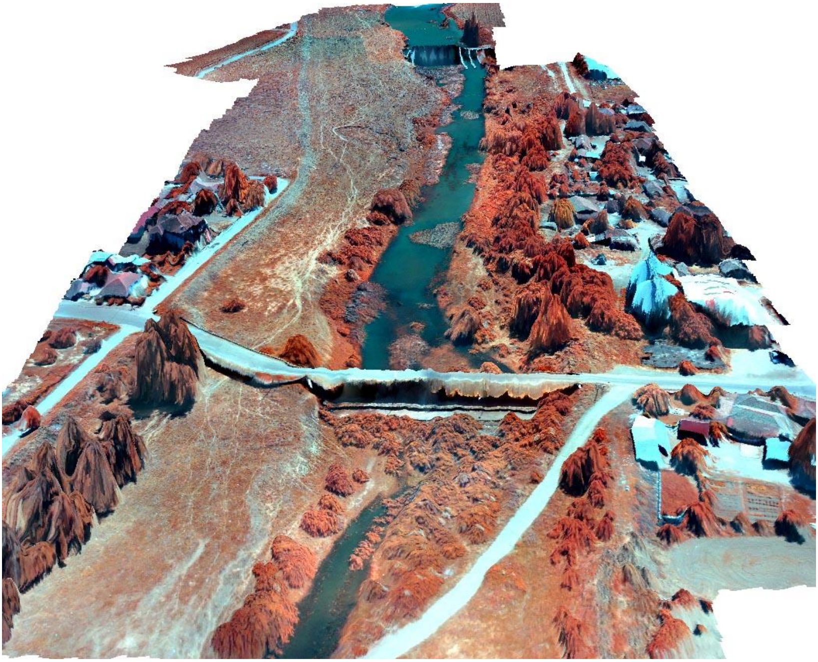

Fig. 1. 3D-imagination of the territory obtained by data of the pilotless aircraft in the region of Volos town in Greece.

by annual agricultural crops or the meadow vegetation. The information on relief in the edges of the field under crop can be affected by natural vegetation or buildings adjacent to this field. The construction of digital relief models is possible only for separate fields. Theoretically the use of data obtained by pilotless aircrafts has to cut down expenses and labor-consuming character of this process as compared to the geodesic survey, but there are no publications devoted to this problem.

The other important trend in using the data of pilotless aircrafts is the monitoring of the crop state. The high spatial resolution of data and the possible survey in the given time allow assessing the state of crops (a great amount of weeds, injury by insects and deceases, the state after winter, stages of phonological development, etc.) and to give a quantitative assessment of crops suffered from several events and their geography (Fig. 2). This information is important both for land owners and the insurance companies, thus permitting to assess the suffered damage.

The most important stage is the geographical position of the obtained images and the correction of geometry and coloring hue. As a rule, these procedures lead infrequently to distortion of initial images but their quality has an influence on the further applied analysis. An example is presented in Fig. 3 illustrating the results of automated classification of images obtained by the pilotless aircraft with the view of assessing the projecting cover of crops and a share of the bare soil surface (about 63%) at the territory of Tula region. The obtained results were based upon the analysis of the imagination obtained by a colored camera, than it was imported into GIS ILWIS and transformed in the local geographical projection. After that three canals were distinguished in the imagination (red, green and blue) to determine the classes of the exposed soil surface and that occupied by the vegetation. The imagination obtained by special cameras in pilotless aircrafts can be more informative. For instance, there are portative cameras permitting to obtain the imagination in canals identical to Landsat satellite or in 12 different canals of surveying in visual and infrared diapasons (the imagination in Fig.1 was obtained by surveying in infrared diapason) as well as multispectral cameras Tetracam for pilotless aircrafts (http://www.tetracam.com).

The use of data obtained by pilotless aircrafts is promising for monitoring of some soil properties and the soil degradation degree in particular as well as for the assessment of soil fertility parameters on several fields. By analogy with satellite methods a role of vegetation can be used as an indicator of the soil state and properties [7]. The most prospecting is the elaboration of approaches to detection of soil properties according to the state of their exposed surface.

At the present time, the solution of this problem is limited by technical impossibility to construct tiny cameras for obtaining the images in narrow spectral diapasons. As soon as the problem will be solved it will be feasible to apply the experience gained in using the aerospace data in this sphere of science.

Based upon the data of standard pilotless aircrafts it seems reasonable to solve some problems of mapping, monitoring and assessment of changes in soil functions.

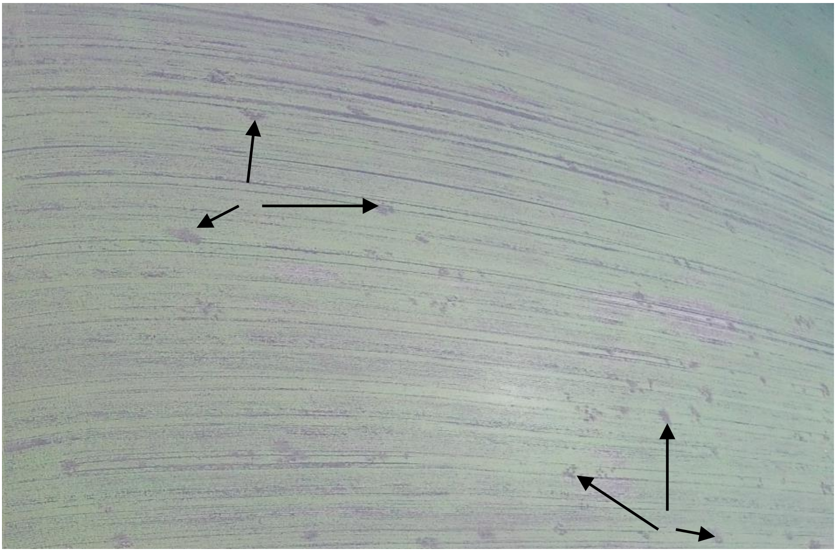

Fig. 2. Sites of the field under winter rye destroyed by field mouses (it is shown by arrows) in the image obtained by the pilotless aircraft (Plavsk, Tula region).

As compared to satellite technologies for surveying definite fields the approaches to use pilotless aircrafts are especially important because they permit to obtain the imagination in any day when the soil surface is open for observation. Fig. 4 presents an example of using the data obtained by the pilotless aircraft for mapping of eroded soils at the territory of experimental station of the V.V. Dokuchaev Soil Science Institute in Tula region.

When analyzing automatically the imagination, it seemed possible to use the procedures and approaches identical to those applied in processing of satellite data. The quality of results depends on the precise geographical position and removal of geometrical distortion in the imagination.

The results presented in Fig. 4 were obtained in the course of analyzing the imagination by the colored camera, imported into GIS ILWIS and transformed in the local geographical projection. Then the imagination was divided into three canals (red, green and blue) to distinguish the classes of the exposed soil surface and that covered by vegetation.

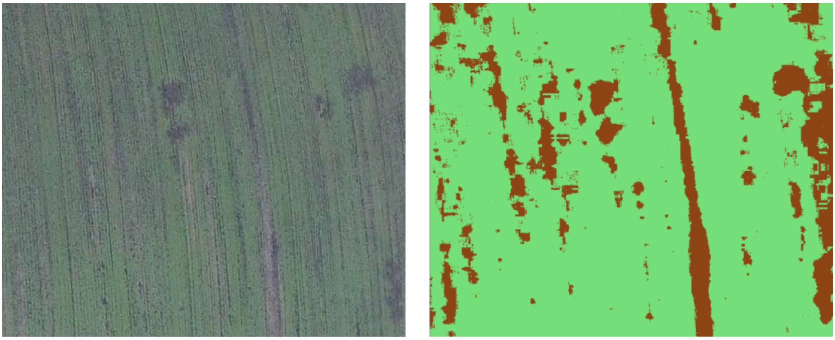

Fig. 3. The imagination of the field under winter rye obtained by the pilotless aircraft divided into two classes (green color into the parts) and the bare soil surface (brown color).

A

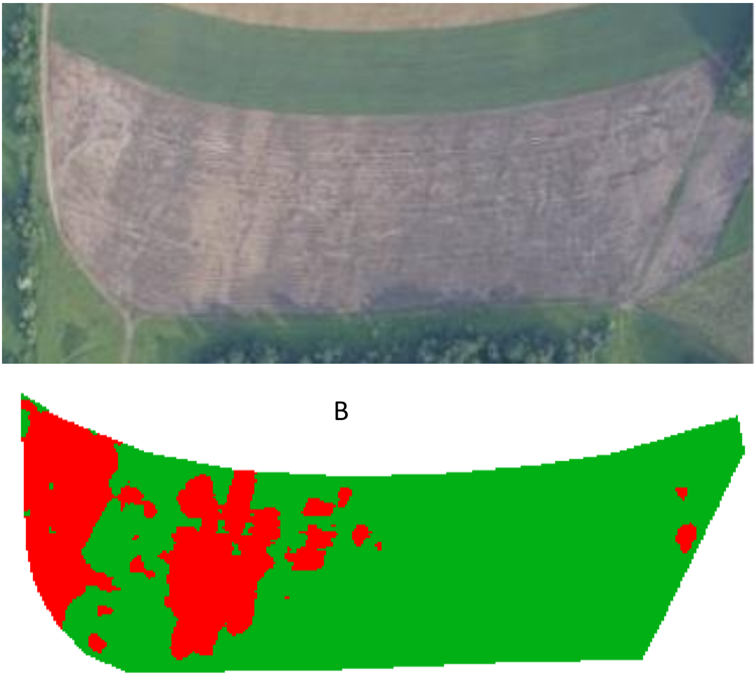

Fig. 4. An example of the automated identification of strongly eroded soils (red color in the parts B) in the imagination obtained by a colored camera of the pilotless aircraft.

The sites of the exposed soil surface were classified once more to identify the class of strongly eroded soils. Under use were picksels and the information on the erodibility degree of soils obtained in field observations.

The examples given above show that the data obtained by pilotless aircrafts may be considered as a cheap and operative alternative of the satellite information on the mapping and monitoring over soils and crops at a level of fields. There are technical problems in the further development of these methods: elaboration of multi-canal portative cameras and modification of approaches to geometrical correction of imaginations. The methods for detection of separate soil properties and parameters of the soil fertility in particular need to be further studied as well. Just this task was formulated in the Program of fundamental investigations approved by the Presidium of Russian Academy of Sciences in 2015.

Acknowledgment. The studies of monitoring over the soil erosion have been carried out at the financial support of Russian Scientific Foundation (grant 15-16-30007).

REFERENCES

1. Andronikov V.L. *Aerokosmicheskie metody izucheniya pochv*, Moscow, 1979. 280 p.

2. Afanas'eva T.V., Trifonova T.A. *Tipologiya poimennykh zemel' r. Obi na osnove kompleksnogo deshifrirovaniya materialov aerokosmicheskoi s"emki* // Vest. Mosk. un-ta. Ser. 17, pochvovedenie, 1983, No. 4, pp. 3–9.

3. *Aerokosmicheskie metody v pochvovedenii i ikh ispol'zovanie v sel'-skom khozyaistve*, Moscow, 1990. 247 p.

4. Vernyuk Yu.I., Anisimov K.B., Bakulin D.A., Gaidarov K.A., Doku-kin P.A., Drozhzhin O.V., Kleshchenko M.M., Kuzin A.V., Nagornyi V.D., Pod-dubskii A.A. *Opyt kompleksnogo primeneniya bespilotnykh i sverkh-legkikh pilotiruemykh letatel'nykh apparatov, sistem global'nogo pozi-tsionirovaniya i geoinformatsionnykh sistem dlya issledovaniya, karto-grafirovaniya i monitoringa pochvennogo i rastitel'nogo pokrova kho-zyaistv* // *Innovatsionnye protsessy v APK*, Moscow, 2013, pp. 423–428.

5. Vernyuk Yu.I., Savin I.Yu., Gaidarov K.A. Opyt primeneniya lokal'-noi aerofotos"emki, geodezicheskikh metodov i GIS tekhnologii pri is-sledovanii pochv i ob"ektov okruzhayushchei sredy dlya ekologicheskoi eks-pertizy // *Nauki o Zemle*, 2012, No. 2, pp. 7–12.

6. Kir'yanova E.Yu., Savin I.Yu. O vozmozhnostyakh otsenki kontrastnosti pochvennogo pokrova Saratovskogo Povolzh'ya po sputnikovym dannym

Landsat // *Tsifrovaya pochvennaya kartografiya: teoreticheskie i eksperi-mental'nye issledovaniya*, Moscow, 2012, pp. 189–209.
7. Kir'yanova E.Yu., Savin I.Yu. Neodnorodnosti posevov, opredelyaemye po sputnikovym dannym MODIS, kak indikator kontrastnosti pochven-nogo pokrova // *Dokl. RASKhN*, 2013, No. 3, pp. 6–39.
8. Konyushkova M.V. Kartografirovanie pochvennogo pokrova i zasolen-nosti pochv solontsovogo kompleksa na osnove tsifrovogo analiza kosmi-cheskoi s"emki: Dis. … k, pp.-kh. n, Moscow, 2010. 300 p.
9. Kravtsova V.I., Nikolaeva p.A. Vozmozhnosti ispol'zovaniya mnogozo-nal'nykh snimkov v issledovanii pochvennogo pokrova // *Kosmicheskaya s"emka i tematicheskoe kartografirovanie*, Moscow, 1979, pp. 148–154.
10. Krenke A.N. Korrektsiya pochvennykh kart na osnove dannykh distantsi-onnogo zondirovaniya i tsifrovoi modeli rel'efa // *Tsifrovaya pochvennaya kartografiya: teoreticheskie i eksperimental'nye issledovaniya*, Moscow, 2012, pp. 284–302.
11. Levengaupt A. I. Opyt primeneniya aerofotos"emki pri izuchenii Dneprovskikh plaven' // *Materialy po probleme Nizhnego Dnepra*, T. 2, 1931, pp. 143–152.
12. Lupyan E.A., Savin I.Yu., Bartalev p.A., Tolpin V.A., Balashov I.V., Plotnikov D.E. Sputnikovyi servis monitoringa sostoyaniya rastitel'-nosti (“Vega”) // *Sovremennye problemy distantsionnogo zondirovaniya Zemli iz kosmosa*, 2011, T. 8, No. 1, pp. 190–198.
13. Puzachenko M.Yu. Mnogomernyi analiz pochvennogo pokrova na osnove polevoi i distantsionnoi informatsii // *Tsifrovaya pochvennaya kartogra-fiya: teoreticheskie i eksperimental'nye issledovaniya*, Moscow, 2012, pp. 252–269.
14. Savin I.Yu. *Deshifrirovanie pochvennogo pokrova lesostepi Tsen-tral'no-chernozemnogo raiona po srednemasshtabnym kosmicheskim snimkam*: Extended abstract of candidate’s thesis, Moscow, 1990. 27 p.
15. Savin I.Yu., Simakova M.S. Sputnikovye tekhnologii dlya inventari-zatsii i monitoringa pochv v Rossii // *Problemy distantsionnogo zondi-rovaniya Zemli iz kosmosa*, Moscow, 2012, T. 9, No. 5, pp. 104–115.
16. Selyakov L. Ya. *Iz opyta Kazakhstanskoi s"emki*, Moscow, 1932.
17. Simakova M.S. *Kartografirovanie pochvennogo pokrova s ispol'zo-vaniem materialov aero- i kosmicheskoi fotos"emki*: Extended abstract of candidate’s thesis, Moscow, 1984, 43 p.
18. Smetanin I.S. Iz opyta ispol'zovaniya materialov aerofotos"emki pri pochvennykh issledovaniyakh // Pochvovedenie, 1940, No. 12, pp. 66–72.
19. Tereshenkov O.M. *Pochvenno-ekologicheskoe kartografirovanie na osnove aerokosmicheskoi informatsii dlya tselei okhrany i optimizatsii pochvennykh resursov*: Extended abstract of Doctor’s thesis, St. Peterburg, 1993, 54 p.

20.Yakushev V.P., Lekomtsev P.V., Matveenko D.A., Petrushin A.F., Yakushev V.V. Primenenie distantsionnogo zondirovaniya v sisteme tochnogo zemledeliya // *Vest. RASKhN*, 2015, No. 1, pp. 23–25.
21.Capolupo A., Pindozzi S., Okello K., Fiorentino N., Boccia L. Photogrammetry for environmental monitoring: The use of drones and hydrological models for detection of soil contaminated by copper // *Sci. Total Environm.*, 2015, Vol. 514, pp. 298–306.
22.Nex F., Remondino F. UAV for 3Dmapping applications: a review // *Appl. Geomat.*, 2014, Vol. 6(1), pp. 1–15. http://dx.doi.org/10.1007/S12518-013-0120-x.
23.Pierrot-Deseilligny M., De Luca L., Remondino F. Automated image-based procedures for accurate artifacts 3D modeling and orthoimage generation // *Geoinforms FCE CTU J.*, 2011, Vol. 6, pp. 291–299.