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# IDENTIFICATION OF AGRI-FIELD CONTOURS BY UAV OF AERO-PHOTOGRAPHY TECHNIQUES

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***Abstract***

*The article considers the methodical approach of determining the soil contours on the basis of aerial photography from an unmanned flying apparatus (drones). On the basis of Brown's model, a map of soil contours is based on aerial photographs taken from the camera of the household segment. A methodical approach to the analysis of soil contours using all three channels of the RGB model is shown. The algorithm describes the numerical values of each soil contour of the study polygons. Described are all polygons that were used for aerial photography. As a result of experience gained, it was found that visual separation of soil-contours is only appropriate with perspective snapshots.*

***Key words**: agri-field, soil contours, aero-photography techniques.*

## INTRODUCTION

As of 2014, Ukraine has no real policy of land monitoring and inventory stock-registration yet. This fact, and a necessity to improve this situation, are evidenced by a series of documents issued by National Council for Safety and Defence of Ukraine (RNBO), and the Decree no.572/2013) by the President of Ukraine. However, this necessity is not a spontaneous effect, for it had been accruing gradually in the course of decades. Soviet Government, aided practice of preparation and formatting agricultural, purpose soil maps in the former USSR (being now of a great concern by present-day Ukrainian agencies, enterprises, institutions and individuals) was suspended in late 1970-ies.

Due to some political and economic reasons, such important efforts were never renewed, nor lots of maps were updated as yet. Accuracy and, moreover, trustworthiness of those 30 years old maps are now obsolete, while, by opinion and estimations of land cadastre experts, their ability to support an assessment and evaluation of agricultural lands and soils is now doubtful (Canash, 2008, 2013). Therefore, a need of implementing relevant studies over the territory of Ukraine becomes a must in oncoming years. However in Ukraine, this task is somewhat problematic due to lack of up-to-date remote sensing equipment, capable of acquisition and transmitting actual soil cover status data to ground operator. In other words, the Ukraine acknowledged space actor does not avail any satellite on orbit. Spatial wide scope data on actual status of national soil cover are only available from overseas paid service space &satellite agencies. This factor still adds to complicacy of the process of getting the urgent data in operative manner. As a result, an acutely needed information is available only with long delay and more than often from archive sources, followed by under fragmentary imaging of any piece of territory of interest in Ukraine. Elaboration of methodology approaches to update and harmonize these issues requires formulation of modern solutions nationwide, from local agencies to Governmental institutional levels.

A subsidiary and, in some cases, an alternative method of obtaining the soil cover status data is aerial photography technique. Regretfully, no massively planned aerial aircraft-aided surveys of soil cover are practiced nowadays in Ukraine, mostly due to deficiency of relevant equipment and aero-photo-lab facilities as yet.

On the other hand, good news appear in recent years that gradually becoming popularized is a technology of aero-photo shooting by aid of unmanned flying vehicles (UAVs) or air model planes (DPLAs), being advantageous to handle and service relatively small (up to 20,000 ha) areas a day. These hand-launched craft do really complement the Great Aviation, which is too huge to barrage over mosaic pattern of agri-fields (Sliva, Demidenko, 2011; Solokha, 2010).

Purpose of this paper is to manifest effectiveness and demonstrate facts and actual achievements gained in operating this kind of equipment accomplished recently in several regions of Ukraine.

Tasks included: creating the methodology and techniques of agrifields' contours status identification; verification of elaborated methodology and techniques' effectiveness by on-ground contact methods; analysis and evaluation of relevant software versions to be used for elaboration of these methodology and techniques etc.

## MATERIALS AND METHODS

Objects of practical studies:

❶ ***Kirovohrad Oblast, Novo-Archangelsk region.*** Land-shooting with DPLA/UAV - craft over the rural territory around Novo-Archangelsk-Torgovitsa-Levkìvka-Sabovo hubs. Geographical coordinates of test-fields centers:

- field no.1: 48.624979 N, 30.798207 E;
- field no.2: 48.627191 N, 30.804985 E;
- field no.3: 48.622785 N, 30.821947 E;
- field no.4: 48.518709 N, 30.802392 E.

❷ ***Kyiv Oblast, Bohuslavsky region.*** Land-shooting with DPLA/UAV - craft over the rural territory around Dibrovka-Huta-Isayki settlements. Geographical coordinates of the test-field center:

- field no. 5: 49.459964 N, 30.796618 E.

❸ ***Kharkiv oblast, Chuhuyiv region.*** "Slobozhansky" pilot field. Geographical coordinates of the test-field center:

$49^0 43'2674''$N. $36^0 55'2333''$E.

**1$^{st}$ phase of work:** *Research type:* classical in the field of soil science. *Way of research:* contact. *Actions within 1$^{st}$ phase of research:* primary cut-outs and reference pit dug-outs.

**2$^{nd}$ phase of work:** *Research type:* the remote. *Way of research:* contactless. *Actions within 2$^{nd}$ phase of research:* air photographing from unmanned remotely piloted super-light air vehicle (DPLA/UAV).

Spectral data were registered using Pentax W60™ camera on board the UAV (Zinčenko, 2011; Sečin et al., 2011). Survey shooting was conducted from different positions and directions of sight-alignment, within 9:30AM to 17:00PM daily in October-November 2013. The UAV average flight altitude over test fields made up 80-100 m high. The air - shooting survey has been practiced intendently under numerous different conditions of various sunlight and cloudy sky illumination levels, with purpose to elaborate methodological data - based solutions to cope with problems that affected accuracy and trustworthiness of the project results.

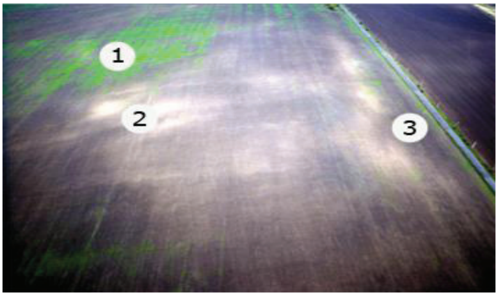
In early practices, contours of fields to be surveyed were flown over at different altitudes and in the geometrically true directions, to systematically cover the overall site area. It soon became clear that such a systemic approach is very bore some and too lengthy (~5 hours for every 100 ha (!). Therefore, route patterns were improved. In a thus improved pattern, a normal route is a combination of several intensive series of upward and downward spirals over a test field. This new approach helped eliminating errors in determining the test-field contours under cloudy sky or at different angles of Sun-inclination, and radically reducing the shooting time (now up to 10 min. per every 100 ha). In this manner, a single flight of DPLA/UAV facilitates ~120-150 photo-shots a session. For the purpose of creating orthophoto maps, the techniques of „stitching together" the aerial photographs (based on Brown's model for correction of image-distortions in pictures) was used. From now on, picture images are processed in a series block. Design of these serial blocks includes: aligning the picture images, constructing ortho-photo-map schematic geometry bases, building plan-texture and consequent saving the project schematics.

The ortho-photo-map is built using both planned and perspective type snapshots (whereby camera shooting axis is $90^o$ only, or scanning between $90^{o}$ and $60^{o}$), correspondingly. Determining the land contours (or non-uniformities) of a test-field was started with a „how-do-you-do” flight by DPLA/UAV over a territory examined. Consecutively, using a set of perspective snapshot images, the contours were identified that still needed verification checks. Having identified field - contours visually, operator has to dig out a chain of standard reference pits, and to ensure log-booking of morphological indices of soil profile. Upon confirmation of land contours, authors proceeded with „stitching the snapshots”, constructing the ortho-photo-map and finally binding up geographically thus derived entries into the [ArcInfo] and [Mapinfo] based on the GIS- package.

## RESULTS AND DISCUSSIONS

Both visual inspection and air survey techniques agreed with fact that land contours differ in colour-tint of their images, which is presumably an impact of granular composition and degree of moisture-supply locations on humus accumulation intensity. A similar effect is evidenced by anthropogenic intervention resulting in soil erosion or even soil-plunder, caused by pipelining, electric power and communication cable-engineering provisions.
It was found that perspective images require visual separation of land contours (spots ①②③ in Figure 1), where by the view (a) is an original snapshot, view (b) is the same image after contrast correction. Owing to this innovative approach, soil-cover defects are clearly expressed and easily identified.

a.

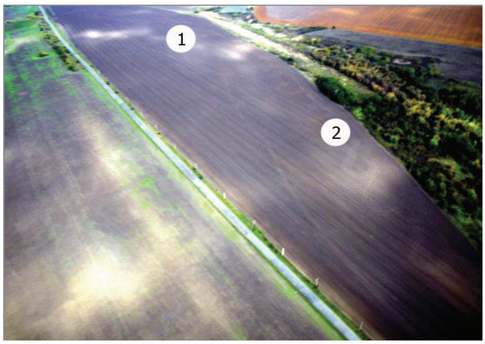



b.

Figure 1. Facts of soil-contour fixation on test-field no. 1

Soil-contours possess the following characteristics:
① - the agricultural vegetation in positive water-supply area, with powerful and thick-humus soil cover.
② - mezo-xero-morphical area on convex side of a slope, under relatively dry conditions.
③ - anthropogenic intervened soil-layer (by electric cable sub-soil construction).

a




b

Figure 2. Facts of soil-contour fixation on test-field no. 2

The test-field no. 2 possesses an eastward ($3^{0}$) slope. Identified contours possess typical indications of runoff towards moisture accumulation areas (①,②) (Figure 2).

Soil-cover with pale spots is a reflexion of typical chernozem soils of various degrees of xero-morph characteristics, together with eroded soils complex.
The test-field no. 3 possesses a westward ($3^0$) slope. Studies revealed habitats of soil bodies under cover of agri-vegetation (Figure 3).

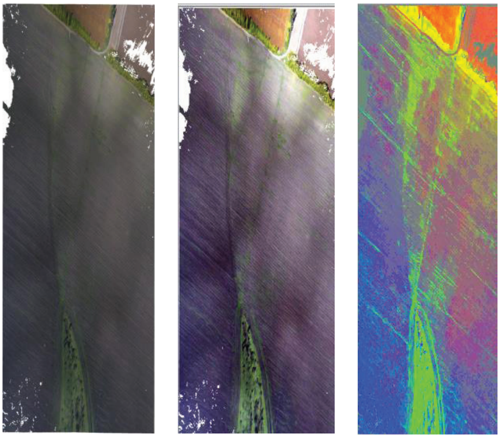
a.


b.

Figure 3. Facts of soil-contour fixation under agricultural plant (soybean) on test-field no. 3

Clearly traced hereby are contours of soy, corn and wheat. On mezo-xero-morphical and heavy-xero-morphical soil areas, the above said agricultural vegetation is in non-uniform status of regress, ripening etc. Many researchers believe that task of soil contour identification under cover of vegetation is a difficult (if ever possible) challenge (Solokha, 2010). Data available with author (Solokha, 2013) still support an idea that usage of phyto-indication method for soil contour fixation is promising to further discoveries.
Characteristic manifestations of xero-morphous flushed-off contours appear in optical band as spots of generally increasing spectral brightness (SB) in all channels of the RGB model. Just for comparison: contours of weed areas possess higher SB-indices in G-channel. At any rate anyway, spectral values of background on all test-fields indicate 70-78 units in all three channels. Hence, contours of xero-morph-eroded soils in optical band are easily identified.
Research study results show that using aero monitoring techniques, one can define micro-relief of any field, as well as hydrological regime characteristics of any its portion. To this end, spectral analysis of UAV-borne photos of winter wheat, shot at "Slobozhansky" pilot field (Kharkiv oblast, Chuhuyiv region) in late April, 2013, has revealed a brighter tinted spot against the dominant colour of all over the test-field. Deficiency of nitrogen plant nutrition, whose diagnostic indication appears as a lowered contents of chlorophyll in vegetative plant organs, could have been caused by activation of dentrification processes in this field-portion. These effects typically occur under anaerobic conditions in over moisture soil cover. In respect of above-mentioned spot, a somewhat lowered micro-relief was identified in contrast to the total surface of the field, whereas supplies of productive moisture stock, within 1-meter deep layer of soil (as of May 23, 2013) exceeded this index for plain-level area by 24 mm.
This implies that early in spring-time, there in the lowered micro-relief area might have occurred appropriate conditions for evolution of dentrification processes, that have eventually led to losses of nitrogen gaseous from soil and decrease in contents of mineral nitrogen compounds. In this manner, usage of aero-monitoring methods for identification of crops' status allows one to manipulate scientifically substantiated agrochemical techniques and to improve efficiency of mineral fertilization by 10-15%, owing to prevention of non-productive losses from nutrient substances.
Let's, for example, consider why not to try the following option: during early spring-time fertilizing of winter grain crops, in area that suffers from low micro-relief, one can apply nitrogen fertilizers in smaller doses than on the rest of the field.
Instead, after some time (i.e. when the soil obtains optimal moisture level and the risk of gaseous nitrogen losses decreases), the prevailing amount of remaining nitrogen fertilizers can be delivered uniformly to fertilize the plants roots.

Now, back to the air shooting campaign: meteorological variations were non-stop (24 h) monitored, especially including cloudy conditions that typically affect quality of aerial snapshots imaging. In space-borne surveillance practice, clouds typically disable chances to conduct identification efforts in optical band of EM-waves. In our project, aero-photo survey was carried out below level of clouds (that hovered at heights from 800 m to 1000 m, visually). To beat harmful effects and probability of image distortions, authors employed their method of spectral processing of thus acquainted ortho-photo maps in environment of [ErdasImage™ - 9.1] (Figure 4).



(a) (b) (c)

Figure 4. Sequence of induced ortho-photo map transformations, to reduce an impact of the „cloud-ceiling" on results of soil-contours identification

This has enabled authors to obtain ortho-photo plans at minimum impact of meteo-factors on soil chart-schemes (Figure 5). Individualization of soil contours was done using colour / tint contrasts of soil cover on slopes, under vegetation, etc. Ready-made orto-photo-plan was loaded into GIS-package to be further processed by standard cartographic tools, to finally obtain a commercially high-quality chart-scheme.
View (a) - shown is field no. 4 (fragmented), whose image was obtained by virtue of [PhotoScan™] ortho-photo-mapping software resource. View (b) - contrasting the ortho-photo-plan brings to amplification of „cloud-ceiling" outlines. View (c) - result of spectral processing of the ortho-photo-plan, manifested by hill-slope coloring and off-field thalweg-pattern.

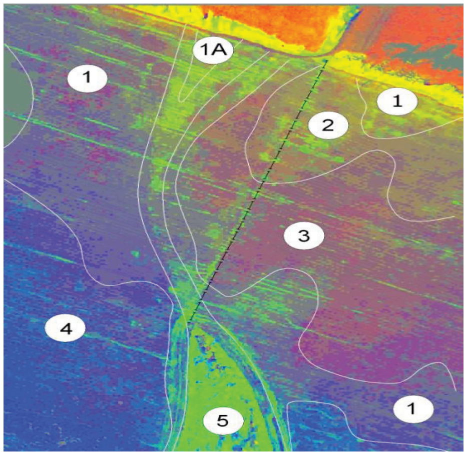



Figure 5. Orto-photo-plan based on the imaging of soil-cover contours:
❶ - typical chernozem; ❷ - typical chernozem black soil, weakly-xero-morphical; ❸ - typical chernozem black soil, mezo-xero-morphical; ❹ - typical chernozem black soil, weakly-xero-morphial; ❺ - the black soil chernozem layer deposited on diluvium sub-stratum; **1A** - typical chernozem of elevated moisture supply; ***Black dotted line:*** an obsolete old-time valley road

When shooting in autumn weather with heavily clouded skies, soil-cover contours(*) were identifiable without extra efforts of contrast and spectral processing (Figure 6).
***Note:** *especially belonging to xero-morph-eroded and light-granulometric content soils.*
Shooting over the same areas in sunny weather has only confirmed the truth of that hypothesis (Figure 7).
View (a) - a convex slope over $5^o$. Light-brown stains reflect flushed-off contours.
View (b) - the rest of the no. 5 field with plain relief expressed by better moisture-supply area on basic relief.
Both in Kirovohrad and Kyiv district areas, contours of xero-morph-eroded soils possess similar spectral brightness indices.
In other words, spectral characteristics of soil-contours in the forest-steppe zone of Ukraine have common features, notwithstanding of latitude dependence amount of solar radiation income.

a.

b.

Figure 6. Field no. 5 (Kyiv district, Boguslav region). Shooting with DPLA/UAV under solid nebulosity

a.

b.

Figure 7. Field no. 5. Control shooting with DPLA/UAV in sunny weather

## CONCLUSIONS

As a result of experience gained, it was found that visual separation of soil-contours is only appropriate with perspective snapshots. Identification of soil-contours occupied by vegetation cover is facile by aid of remote techniques; whereby factors of special importance are status of vegetation, time of shooting and latitude. Employment of Brown model at plotting soil- chart-plans and schemes, as well as identification of agri-crop contours, opens broad prospects. Brown model implementation is available with [PhotoScan] software resource. However, whilst shooting land objects of specific features (like cross country forest strips of agricultural buildings, structures etc.), there exist certain limitations against application of Brown model. When plotting the Brown model derivation, images undergo distortion and thus, this technique is regretfully helpless at measurement of specific soil contour areas. Xero-morph-eroded soils possess a significant spectral brightness, even being occupied by any agri-vegetation. Values of SB-index range between 80 and 130.

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