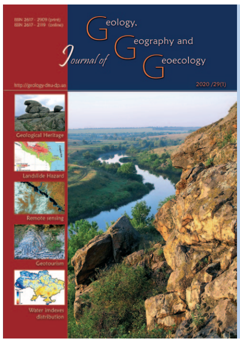

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Remote and ground-based observations of land cover restoration after forest reclamation within a brown coal basin

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Abstract. The Semyonovsky - Golovkovsky brown - coal deposit is located within the boundaries of the Dnieper basin geological group and is located in the Alexandria mining region on the watershed of the Ingulets and Beshka rivers. Overburden rocks are loess - like, red - brown and glauconite - containing loams, kaolin and carbonaceous clays quartz, glauconite - containing and carbonaceous sands. The total area of reclaimed land was about 1006 hectares, of which 39 % was used for agriculture, 2 % was pasture and 59 % under forest reclamation. Geomorphologic assessment of the studied area was performed using Sentinel-1 satellite radar interferometry. Multispectral imagery of Sentinel -2 satellite system was used for remote assessment within the study area. We assessed the state of the *Robina pseudoacacia* plants growing under various forest conditions, in plantations created on the reclaimed landscapes of the Semenovsky - Golovkovsky brown coal basin. The processes of self-regulation and restoration of fertility on the reclaimed lands at the first stages of their biological development were slowed down. This significantly reduced the resistance of phytocenoses, both pure and mixed, to the conditions of the environment to which they were exposed. A comparison of the inventory stem wood of the black locust showed the superiority of monoculture plantations to mixed stands of pine - black locust and maple - black locust. The forest-forming process progresses with age. Remote assessment of the territories was conducted to assess the future prospects of biological conservation of reclaimed lands. The influence of the anthropogenic factor is observed throughout the section and is manifested in the man-made formation of the relief, reshaping of dumps, removal to the surface of overburden rocks. It is established that the height values can vary from 85 m to 213 m. 82.8 % of the surveyed area has not undergone significant changes in relief. About 15.5 % of the territory was under the influence of alluvial - diluvia processes. There have been corresponding changes in the share of vegetation according to vegetation cover fraction (VCF) over the past three years. The highest moisture content at the level of 0.2 - 0.3 relative units in 2015 was recorded in the territory occupying 78.4 % . Meanwhile, the shares of land cover with this level of humidity increased by almost 9% during the following 3 years to 2018. The highest density of vegetative cover was recorded in the North -Western part of the study area of forest reclamation. Thus, considering the potential suitability of the area for forest reclamation, we should note the important role of geomorphological, geological and water resources for the growth and development (formation) of plant communities

Key words: forest reclamation, land cover, remote sensing

Дистанційні та наземні спостереження відновлення земельного покрову після лісової рекультивації у буровугільному басейні

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Анотація. Семеновсько-Головківське буровугільне родовище знаходиться в межах геологічної групи Дніпровського басейну і розташоване в Олександрійському районі на вододілі річок Інгулець і Бешка. Воно являє собою відпрацьований кар'єр на денну поверхню якого винесені гірські породи надвугільної товщі. Розкривні породи представлені лесоподібними, червоно-бурими і глауконітвміщуючими суглинками, каоліновими і вуглистими глинами, глауконітовими і вуглистими пісками. Загальна площа рекультивованих земель склала близько 1006 га, з них під сільськогосподарськими угіддями – 39 % території, пасовищами – 2 % і під лісовою рекультивацією – 59 %. Геоморфологічну оцінку досліджуваної території було проведено із застосуванням супутникової радарної інтерферометрії Sentinel-1. Багатоспектральні знімки супутникової системи Sentinel-2 було використано для дистанційного спостереження досліджуваної території. Наведена оцінка стану насаджень робінії звичайної, що вирощується в різних лісорослинних умовах штучно створених на рекультивованих землях Семенівсько-Головківського буровугільного розрізу. Процеси саморегуляції та відновлення родючості на рекультивованих землях на перших етапах їх біологічного освоєння були сильно загальмовані. Це значно знижувало стійкість білоакацієвих фітоценозів, як чистих, так і змішаних, до умов наданого їм середовища. Прогрес формування лісових насаджень відбувається з віком. Дистанційна оцінка територій проводилася з метою оцінки перспектив біологічної консервації рекультивованих земель. Вплив антропогенного фактору спостерігається по всьому розрізу і проявляється в техногенному формуванні рельєфу, переформуванні відвалів, виносі на поверхню розкривних порід. Встановлено, що значення висоти можуть варіюватися від 85 м до 213 м. 82,8% обстеженої території не зазнали істотних змін рельєфу. Близько 15,5% території перебувало під впливом алювіально - делювіальних процесів. За останні 3 роки відмічені і відповідні зміни частки рослинного покриву через проективне покриття рослинності. Найбільший вологовміст на рівні 0,2 - 0,3 відносних одиниць в 2015 році зафіксовано на території, що займає 78,4 %. Тим часом, частка ґрунтово-рослинного покриву з такою вологістю збільшилася у 2018 році майже на 9 % протягом трьох років. Найбільша густота рослинного покриву відзначена в північно - західній частині досліджуваної території лісомеліорації. Таким чином, розглядаючи потенційну придатність території для меліорації лісів, слід відзначити важливу роль геоморфологічних, геологічних і водних ресурсів для зростання і розвитку (формування) рослинних угруповань

Ключові слова: лісова рекультивація, земельний покрив, дистанційні спостереження

Introduction. Overburden rocks in the mining process are removed by excavation. This leads to permanent changes in topography and geological structures, and disrupts the surface and subsurface hydrologic regime (Shrestha and Lal, 2011). In particular, fertile soil mixed with fragmented rocks is transported to form large - scale dumps (Zhao et al., 2013) and forest vegetation is removed with some forest biomass harvested and most bulldozed into piles and burned (Amichev et al., 2008). The natural succession process of both soil and vegetation in dumps requires a lot of time, during which, the dumps are exposed to wind and water erosion processes (Zhao et al., 2015). Thereby, restoration of soil and vegetation within a short-time period is a high priority for opencast coal mine reclamation. Meanwhile, the reclaimed mined ecosystem could be regarded as an “empty cup” with large potential to store tremendous amounts of soil nutrients and vegetation biomass (Chatterjee et al., 2009), which provides a platform to conduct both remote and ground based sensing of the development of soil and vegetation from scratch.

Composition, properties, natural overgrowth and suitability of overburden rocks for land reclamation are described in numerous case studies (Zipper, 2000; Sobek et al., 2000; Likus-Cieślik and Pietrzykowski, 2017). The suitability of dumps for afforestation with different tree and shrub species has been studied on the basis of different approaches (Casselman et al., 2006; Schaaf et al., 2000). Normal practice for re-vegetation is selecting drought-resistant, fast growing crops or fodder crops which can grow in nutrient deficient soils. In certain areas, the main factor in preventing vegetation is acidity. Plants must be tolerant of metal contaminants typically present at such sites (Caravaca et al., 2002; Mendez and Maier, 2008). Compaction and texture of replaced soil during reclamation of surface - mined land can limit tree growth (Cleveland and Kjelgren, 1994). Re-forestation with black locust (*Robinia pseudoacacia*) is considered a successful technique that is often used for the reclamation of open-cast mine areas (Vlachodimos et al., 2013; Sytnyk et al., 2016). *R. pseudoacacia* as a nitrogen-fixing plant enriches soil with organic and inorganic nitrogen and organic matter to a greater extent than natural grasses. Most physicochemical properties in reclaimed mine soils under *R. pseudoacacia* monoculture forest become considerably elevated with the duration of the reclamation period compared to undisturbed soils. The duration required to attain the nutrient level in undisturbed soils was about 10 years of reclamation. Overall, *R. pseudoacacia* has shown strong adaptation to poor soil conditions after reclamation and has markedly ameliorated soil succession in dumps (Yuan et al., 2018).

The reactions to mixture of ores and their change along a gradient of site conditions depend on the respective limiting factor and the species’ potential to overcome the limitation (Forrester, 2014). Complementarity in exploitation of water and mineral nutrients is most effective and growth accelerating on sites with limitation in water and mineral nutrients. Mixed stands of Scots pine and European beech have significantly higher structural heterogeneity than monocultures of Scots pine and European beech (Pretzsch et al., 2016). Comparison based on total biomass production may bring different results, as mixing tree species can change stem-crown allometry (Pretzsch, 2014; Liang et al., 2016; Vallet and Perot, 2016) and also tree ring width and wood density (Zeller, 2016). Tree species mixing can significantly modify individual tree morphology and reduce or improve wood quality (Pretzsch and Rais, 2016).

A successful reclamation programme must include a monitoring component to identify areas of successful reclamation, as well as areas where management problems exist or where reclamation practices are failing (Lein, 2001). Monitoring of the natural environment, especially areas degraded by mining activities, is connected with the constant need for precise and up - to - date land use/land cover maps (Szostak et al., 2015; Townsend et al., 2009). Novel techniques including geoinformation technologies such as those used in making land use and land cover change maps are used for characterizing the morphometry and determination of the spatial structure of vegetation on reclaimed post-mining areas (Chmielewski et al., 2014; Dudzińska - Nowak and Wężyk, 2013; Szostak et al., 2014; Wężyk et al., 2014). Remote sensing data are useful for the investigation and monitoring of vegetation change in open pit mining areas over a long period of time. This method is useful to identify areas where vegetation may be stressed, or where reclamation requires integrated approaches (Szostak and Nowicka, 2013; Maiti et al., 2019).

The aim of our research was to make a geospatial assessment of land cover after the extraction of brown coal and the technical stage of **r**eclamation of disturbed areas.

Materials and methods. The Dnipro brown coal basin occupies an area the size of more 60 000 km^2. 12 brown coal areas are part of this basin. The surface of the basin is characterized as an elevated gently undulating plain, sometimes dissected by river valleys and a dense network of gullies and ravines.

Expressed dismembered relief causes the development of surface runoff. This is a factor in the formation of eroded lands with varying degrees of washout. This part of the area is affected by deep erosion. Artificial landforms in the basin are also observed together with natural geomorphological forms. These are quarry pits, trenches, overburden dumps, deformed surfaces, etc. A characteristic feature of the climate is quite a significant fluctuation in temperature and rainfall over the months.

Availability of soil productive moisture for plants is average. Approximately every fourth to fifth year is dry, due to insufficient rainfall in the spring and summer. Quite often there is a decrease (less than 50 % of the field moisture capacity) of moisture reserves, which coincides with the air drought – dry winds. Common species of forest stands are oak, ash, maple, elm, and linden).

The Semyonovsky-Golovkovsky brown - coal deposit is located within the boundaries of the group of the Dnieper basin and is located in the Alexandria mining region on the watershed of the Ingulets and Beshka rivers. Overburden rocks are loess - like, red - brown and glauconite - containing loams, quartz, glauconite -containing and carbonaceous sands, kaolin and carbonaceous clays. The total area of reclaimed land was about 1006 hectares, of which under agricultural land occupied 39 % of the territory, pastures 2 % and land under forest reclamation – 59 %.

Overburden rocks are characterized by different texture and origin. Their uptake to the earth's surface, together with man-made dismemberment of the terrain, creates many options for the development of various forest trees and shrubs. 15 sample plots (SA) were laid in the last decade of the 20th century in the Alexandria forestry. Forest species were planted in five sites (blocks) of different age (5 - 30 years), composition of stand (pure and mixed) and different technozem composition. Rocks were represented by deposits of neogenic and anthropogenic periods with different textures: loamy, clay, sand. The sites selected for the creation of forest plantations were characterized by state of moisture and attachment to different elements of the relief. The survey of the structure and productivity of the forest stand was carried out in accordance with the requirements of forest inventory. Plantations of black locust (*Robinia pseudoacacia*) on technozems occupied 150.6 ha, representing 27 % of the total reclaimed area. Due to its biological features and environmental needs, the culture of black locust was used for various applications in the restoration of disturbed lands. Mixed stands occupy an area of 58 ha, of which pine or *Pinus sylvestris L.*(*P.s.*) – black locust or *Robinia pseudoacacia* (*R.p.*) account for 47 % of the territory and maple-black locust – 33 %.

Geomorphological assessment of the studied area was performed using multitemporal satellite radar interferometry. Multispectral imagery of Sentinel-2 satellite system was engaged for remote land cover assessment within the study area. Relative soil moisture for the territory of the Semyonovsky – Golovkovsky brown-coal deposit area was estimated using the Sentinel-2 Multispectral Instrument (MSI), Landsat-8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) optical multispectral data. Standard preprocessing operations including radiometric calibration, atmospheric correction and cloud masking were applied to input multispectral images. The Landsat-8 OLI/TIRS 30 m spatial resolution imagery was used to calculate true (not radiant) temperature T of land surface, while the Sentinel-2 MSI 10 m spatial resolution imagery produces the Normalized Water Index (NWI) (Sakhatsky and Stankevich, 2007). Both T and NDWI maps after co-registration was fused into land surface water content distribution (Zhang and Zhou, 2016). Normalized Difference Vegetation Index (NDVI) was computed to determine Vegetation Cover Fraction (VCF) (Zhang et al., 2006) based on Sentinel-2 Alexandria – Golovkovka 2015.08.09 and 2018.06.19 images.

Results and discussion. There is a wide variety in the spatial structure of phytocenoses in the studied plantations of black locust, depending on the diversity of forest growth conditions. The influence of the anthropogenic factor is observed throughout the coal basin and is manifested in the technogenic formation of relief, reshaping of dumps, uptake of overburden rocks to the day surface of the lignite deposit. Elevations alternate with depressions. This causes the diversity of the soil cover, both in fertility and moisture. Dynamics of forest mensuration indices of pure stands of black locust are shown in Fig.1.

– year - old *Robinia pseudoacacia* stands, which are in decline and are represented by loamy sediments, occupy the largest area. The range of moisture varies from moist to wet loams. The height of the stand was 11 - 12 m, diameter – 12 - 14 cm, wood reserves – 83 - 96 m^3/ha, respectively. It should be noted that the average growth rates reached the maximum values at the age of 20 - 25 years – 3.84 – 4.15 m^3, and the current in 15 - 20 years – 7.8 - 9.5 m^3.

Some approaches have been applied in connection with the slow growth of forest crops on the dumps to intensify the growth processes. Use of methods of biological intensification of growth of tree cultures gave good results. One of them is the introduction of nitrogen fixing species into the forestry culture. Thus,

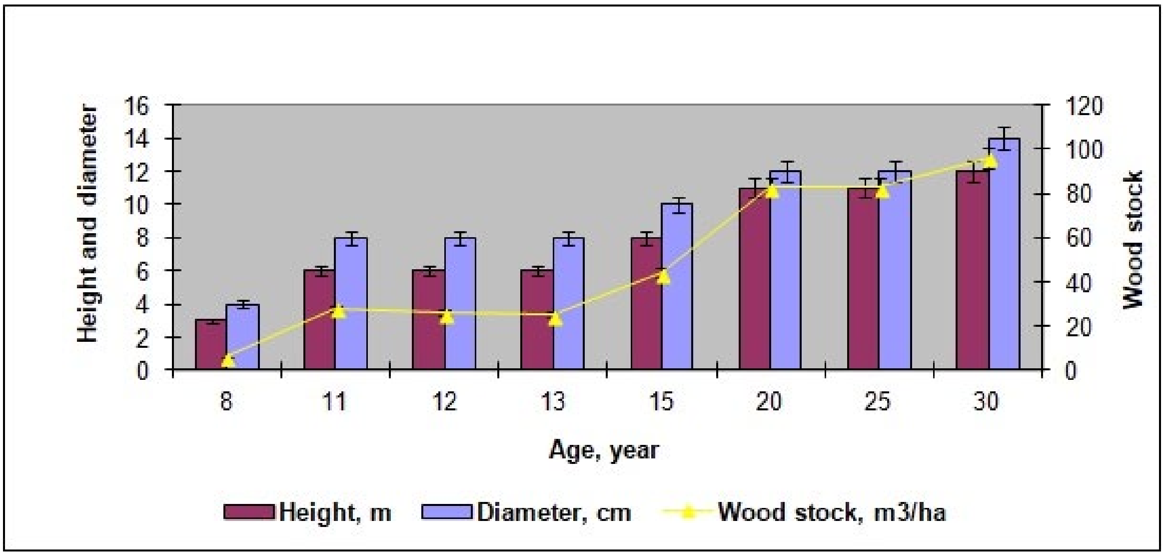


Fig. 1. Dynamics of parameters of plantations of *Robinia pseudoacacia*

Eight-year plantings were located on the slope of the eastern exposure and differed in the lowest indices of forest inventory: height – 3.0±0.034 m, diameter – 4.01±0.06 cm, wood stock is 6.03±0.06 m^3/ha.

The virgin plantings of black locust at the age of 11 - 13 years reached a height of 6.12±0.08 m and a diameter of 8.1±0.10 cm. There was a differentiation of wood stocks of 25 - 28 m^3/ha and fluctuations in the average growth from 1.92 to 2.55 m^3. 15-year-old plantations of *Robinia pseudoacacia* in the ravine thalweg on loamy rocks in wet conditions of moisture were surrounded by steep slopes of the south-western and north - eastern exposures. The forest stand had an average height of 7.98±0.10 m, an average diameter of 10.04±0.15 cm, wood reserves – 44.03±0.25 m^3/ha. Black locust aged 20 years has a stock of stem wood 83.1±0.40 m^3/ha. Maximum forest growth effect of acacia on reclaimed lands was expressed in the average growth achieved at this age. The mono 25

plantations were created in which 40 % was occupied by Scots pine and 60 % by *Robinia pseudoacacia* (Fig.2).

Plantings with the composition of the stand 6R.p.4P.s. formed in the upper third of the waste of the Western exposure on loamy sediments. Wood reserves amounted to 12.07 ±0.12m^3/ha. Black locust had a height of 4.05±0.07 m, diameter – 6.06±0.09 cm, pine – 3.03±0.07m and 3.98±0.09cm respectively. It was found that with this ratio of tree species to 11 years of age, *Robinia pseudoacacia* was ahead of pine in terms of growth. The advantage of pure pine plantations was established on all parameters (altitude 33%, diameter by 50 % and stocks of wood at 100 %). Plants of *Robinia pseudoacacia* of natural origin penetrate with a decrease in the completeness of the monoculture of pine from the surrounding areas, ahead of the growth of the 11 - year - old pine (10P.s. + R.p.). In the future, with age (19 and 21 years),

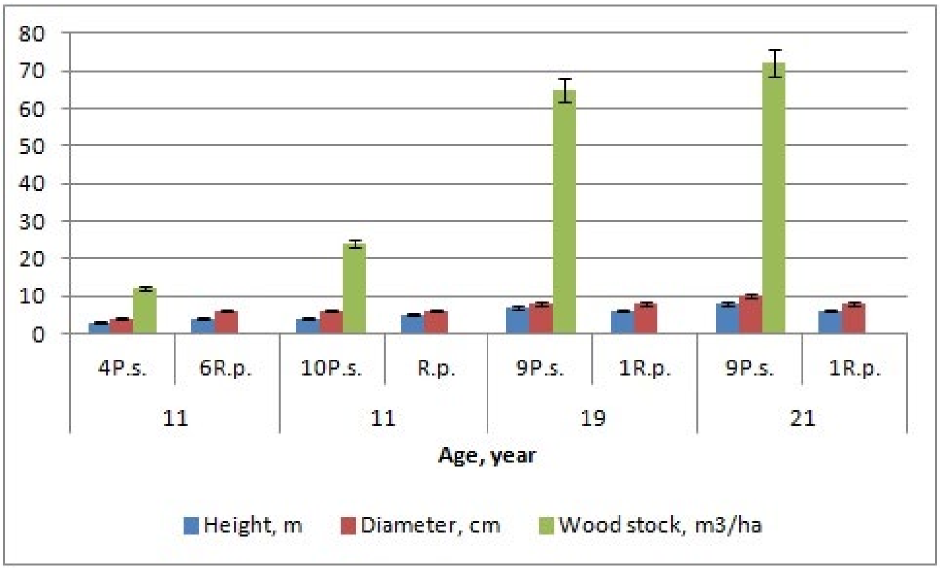


Fig. 2. Wood stocks in mixed forest stand of pine (*P.s.*) and black locust (*R.p.*)

Robinia pseudoacacia of natural origin is introduced into the monoculture of pine by 10 % (9P.s.1R.p.). However, it is significantly inferior to the growth rate of the main plant, especially in terms of wood reserves.

Mixed stands of the same age with different structure of the forest stand with the participation of *Robinia pseudoacacia* present another area of interest. Two sample areas had the same composition of 7 Black locusts + 3 Maples or *Acer pseudoplatanus L.*(*A.p.*) aged 10 years, but differing in geological conditions, which led to a change in the parameters of forest taxation (Fig. 3).

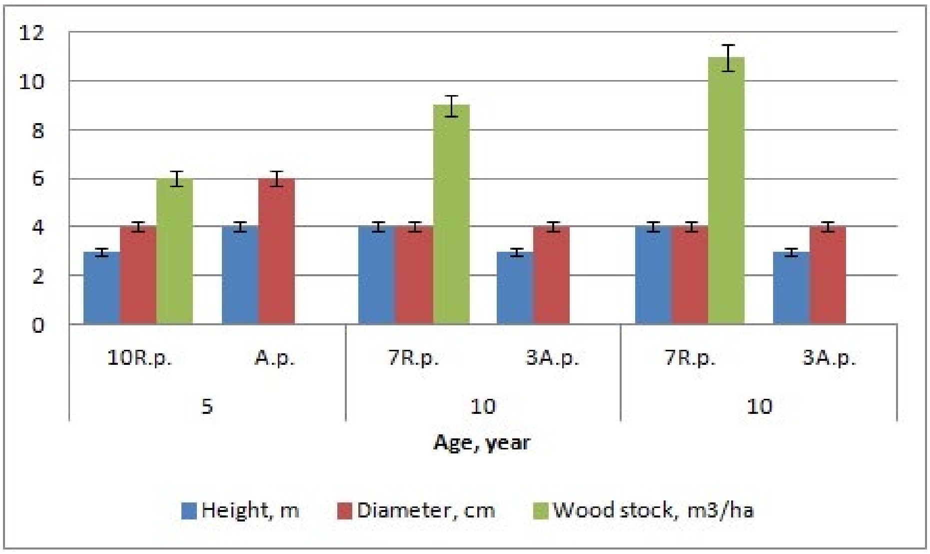


Fig. 3. Wood stocks in mixed forest stand of pine and black locust

Maple at the age of 10 years occupies up to 30 % of such areas. Comparing the same structure of the forest stand phytocenosis (7R.p. + 3A.p.), growing in different conditions on washed and leveled areas, we can note that the wood reserves on the leveled areas were 22 % higher due to greater completeness.

Results of previous similar case studies comparing the same experimental pure and mixed-species plantations have shown that productivities were either similar or greater than the same species grown in monocultures (Piotto et al., 2003; Alice et al., 2004; Petit and Montagnini, 2004; Petit and Montagnini, 2006). Meantime, it was established that mixed - species plantations have greater potential advantages than monocultures (Mao et al., 2017). The greatest use of melioration in forest plantations is through the combination of a Nitrogen (N) - fixing and a non - N - fixing tree species (Kelty, 2006). N - fixing tree species may increase the supply of available N in the soil, benefiting both N - fixing and non - N - fixing trees. Strong facilitative effects of N - fixing species on the growth of non - N - fixing species were found on a site with low soil N, but not on a site with high soil N (Bouillet et al., 2013).Trees and shrubs in the territory of a lignite deposit after the biological stage of reclamation were both in pure and in mixed condition.

Thus, *Robinia pseudoacacia* monocultures on territories of reclaimed mines had higher values of height, diameter and productivity. These plantations at the age of 5 - 11 years exceeded at this stage the dynamics of growth and wood reserves of mixed plantations. The similar results have been obtained in case studies (Bouillet et al., 2013; Mao et al., 2017; Kelty et al., 2006; Pretzsch, 2014).

The highly dynamic process of the secondary forest succession has been shown on the tested areas of sulfur mines (Szostak et al., 2015).

Results of remote sensing of geomorphological features of the reclaimed area (terrain relief features formed in the post-reclaimed period). The studied area terrain elevations are shown in Fig.4.

The influence of the anthropogenic factor is observed throughout the section and is manifested in the man-made formation of relief, reshaping of dumps, removal to the surface of overburden rocks. It is established that the height values can vary from 85 m to 213 m. The results of these changes in the microrelief for the last 3 years (from 2015 to 2018) are presented in Figure 5 and Table 1.

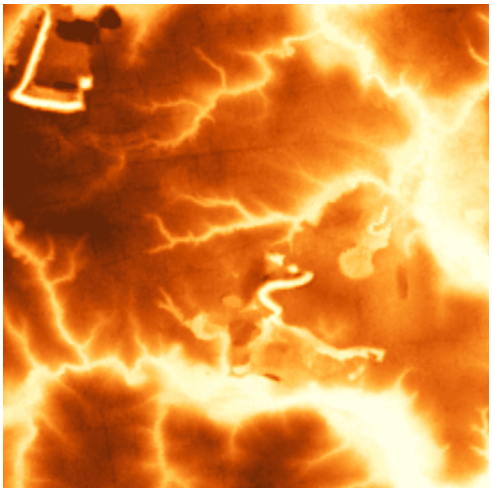


Fig. 4. Terrain elevations within the study area (Sentinel-1A Alexandria – Golovkovka 2018.06.08 / 2018.06.20 interferometric pair)

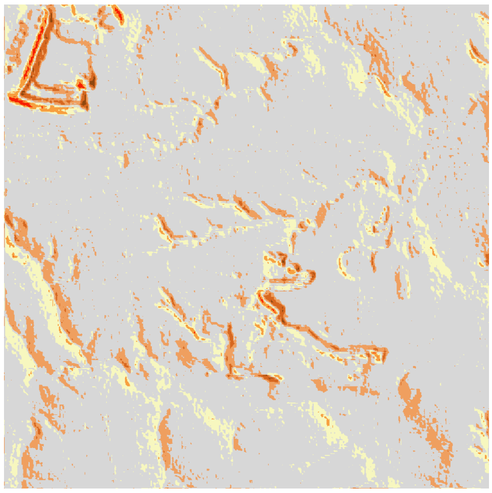


Fig. 5. Terrain elevation change within the study area (Sentinel-1, Alexandria – Golovkovka 2015.08 – 2018.06)

Table 1. Legend of terrain elevation change

Code	Colour	Class	Difference	Percent
0		Unclassified	no data	0.0000
1		Strong Down	< –0.30	0.1223
2		Moderate Down	–0.30 .. –0.15	0.7967
3		Weak Down	–0.15 .. –0.05	8.0757
4		No Change	–0.05 .. 0.05	82.7699
5		Weak Rise	0.05 .. 0.15	7.3865
6		Moderate Rise	0.15 .. 0.30	0.7891
7		Strong Rise	> 0.30	0.0597

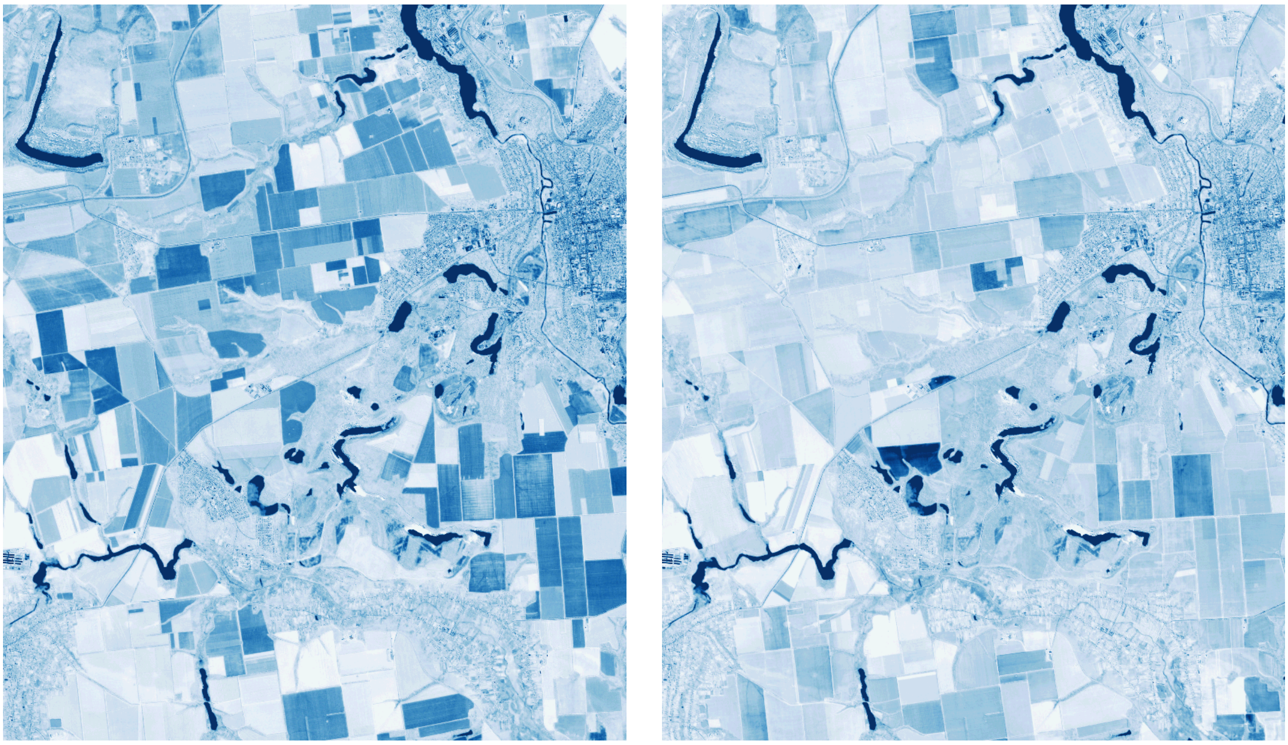
According to the data obtained, 82.8 % of the surveyed area has not undergone significant changes in terrain elevation. About 15.5% of the territory was under the influence of alluvial-diluvia processes.

Data on the distribution of land surface water content in the summer of 2015 and 2018 within the surveyed area are shown in Fig.6 and Table 2. The logarithmic regression relationship between the $^{(NWI+1)}/_{T}$ parameter and relative water content was restored therefor.

Elevations alternate with depressions, which causes the diversity of the soil cover, both in fertility and moisture.

The highest moisture content at the level of 0.2 - 0.3 relative units in 2015 was recorded in the territory occupying 78.4 %. Meanwhile, the shares of land cover with such humidity increased by almost 9% over the next 3 years.

VCF image differencing is successfully used to follow the long-term success of reclamation (Sarp,

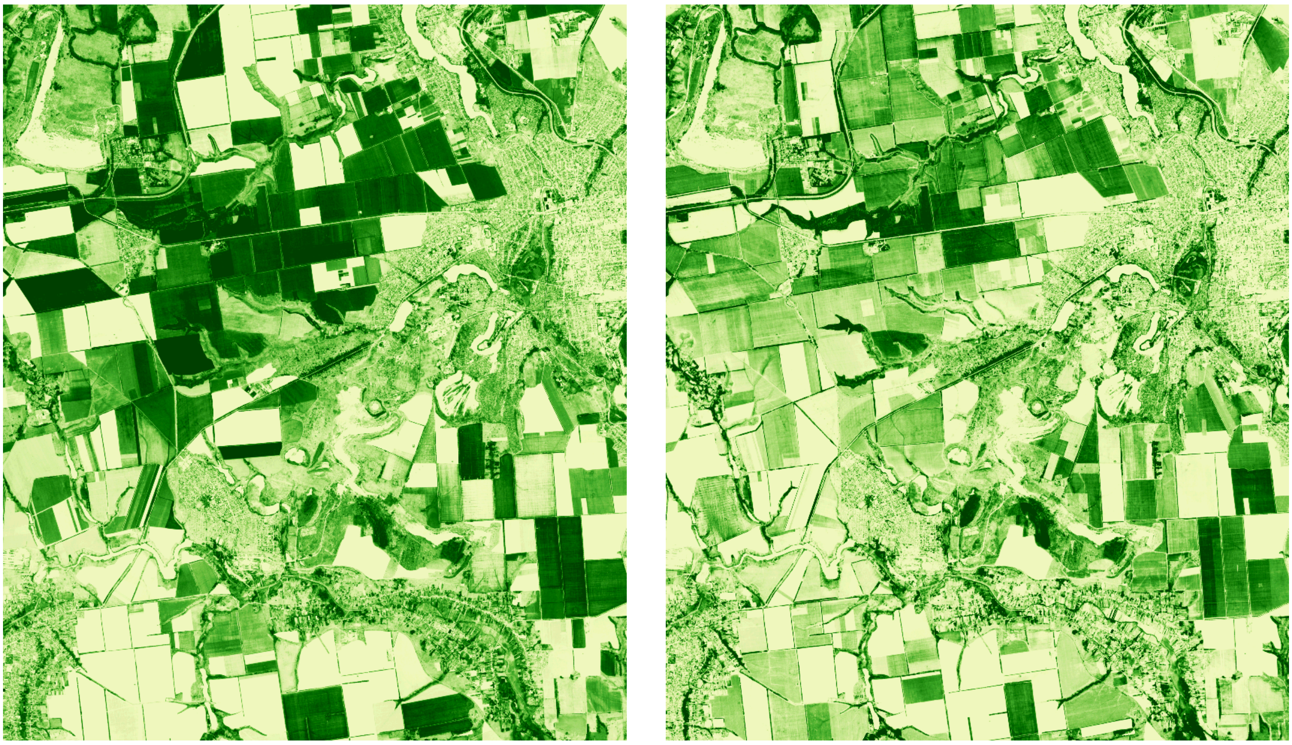


2015.08.09 2018.06.19

Fig. 6. Water content distribution maps, Sentinel-2, Alexandria – Golovkovka

Table 2. Legend of water content estimation

Code	Colour	Value	Percent	Value	Percent
		2015.08.09		2018.06.19	
0		no data	0.0000	no data	0.0000
1		0.0 – 0.1	0.0003	0.0 – 0.1	0.0014
2		0.1 – 0.2	1.3803	0.1 – 0.2	2.8939
3		0.2 – 0.3	78.3774	0.2 – 0.3	87.2895
4		0.3 – 0.4	18.1562	0.3 – 0.4	7.3259
5		0.4 – 0.5	0.3683	0.4 – 0.5	0.7078
6		0.5 – 0.6	0.2010	0.5 – 0.6	0.2217
7		0.6 – 0.7	0.2854	0.6 – 0.7	0.3207
8		0.7 – 0.8	0.9052	0.7 – 0.8	0.9199
9		0.8 – 0.9	0.3259	0.8 – 0.9	0.3192



2015.08.09 2018.06.19

Fig. 7. Vegetation cover fraction maps, Sentinel-2, Alexandria – Golovkovka

Table 3. Legend of VCF parameters

Code	Colour	Value	Percent	Value	Percent
		2015.08.09		2018.06.19	
0		no data	0.0000	no data	0.0000
1		0.0 – 0.1	25.6841	0.0 – 0.1	29.2965
2		0.1 – 0.2	8.6552	0.1 – 0.2	12.5878
3		0.2 – 0.3	9.0779	0.2 – 0.3	12.7751
4		0.3 – 0.4	9.4638	0.3 – 0.4	11.4648
5		0.4 – 0.5	8.6933	0.4 – 0.5	8.8962
6		0.5 – 0.6	7.6262	0.5 – 0.6	7.1871
7		0.6 – 0.7	6.3338	0.6 – 0.7	6.5164
8		0.7 – 0.8	7.1992	0.7 – 0.8	5.2522
9		0.8 – 0.9	10.3037	0.8 – 0.9	3.9347
10		0.9 – 1.0	6.9628	0.9 – 1.0	2.0892

2012). The classic method for NDVI-based VCF calculating from Carlson & Ripley paper (Carlson and Ripley,1997) was used:

$$VCF(x, y) = [(NDVI(x, y) - NDVI_0)/(NDVI_1 - NDVI_0)]^2 ,$$

where $VCF(x, y)$ is VCF value inside (x, y) image element, $NDVI_0$ and $NDVI_1$ are NDVI thresholds values for vegetation-free and full vegetation cover terrain respectively.

Data on the state of vegetation cover in the summer of 2015 and 2018 in the surveyed area are shown in Fig.7 and Table 3.

The VCF differentiation allows separation of vegetated areas from areas with little or no vegetative cover. High VCF values are mostly indicated for reclaimed and vegetated areas. The highest density of vegetative cover was recorded in the North-Western part of the study area of forest reclamation. At the same time, vegetation cover fraction over the past three years decreased by codes 8-10 and increased by codes 1, 3, 4. Thus, considering the potential suitability of the area for forest reclamation, one should note the important role of geomorphological, geological and water resources for the growth and development (formation) of plant communities.

Conclusion. The processes of self-regulation and restoration of fertility on reclaimed lands at the first stages of their biological development were slowed down. This significantly reduced the resistance of phytocenoses, both pure and mixed, to the conditions of the environment provided to them. A comparison of the inventory stem wood of the black locust showed the superiority of monoculture plantations to mixed stands of pine-black locust and maple - black locust. Progression of the forest-forming process takes place with age. Remote assessment of the territories was conducted to assess the future prospects of biological conservation of reclaimed lands. The influence of the anthropogenic factor is observed throughout the section and is manifested in the man - made formation of relief, reshaping of dumps, removal to the surface of overburden rocks. It is established that the terrain's height values can vary from 85 m to 213 m. 82.8 % of the surveyed area has not undergone significant changes in relief. About 15.5 % of the territory was under the influence of alluvial - diluvia processes. There have been corresponding changes in the share of vegetation using the VCF value codes over the past three years. The highest moisture content at the level of 0.2 - 0.3 relative units in 2015 was recorded in the territory occupying 78.4 %. Meanwhile, the shares of land cover with such humidity increased by almost 9 % over the next 3 years. The highest density of vegetative cover was recorded in the North - Western part of the study area of forest reclamation.

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