ANALYSIS OF THE CHANGE IN VEGETATION COVERAGE OF CHALK SOIL WASTELAND DURING THE GROWING SEASON BASED ON UAV SEQUENCE IMAGE

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Abstract. Normalized Difference Vegetation Index (NDVI), the most widely applied vegetation index, can accurately reflect the vegetation coverage and growth on chalk soil wasteland, and provide bases for the further optimization of vegetation. In this research, a chalk soil wasteland located in Fengquan District of Xinxiang city of China was taken as the study target, and photos of the vegetation coverage of the chalk soil wasteland during the growing season (March to October) were taken with a multispectral camera carried on Dajiang unmanned aerial vehicle (UAV). The results have shown that the mean NDVI of the wasteland during the growing season is 0.21. After almost two decades of treatment, the ecological environment improves, but it just reaches medium coverage. The monthly mean NDVI of the wasteland during the growing season ranges between 0.12 and 0.30, which is of medium coverage or level below. The monthly NDVI level distribution of the wasteland during the growing season indicates that the ratio of high vegetation coverage is relatively low, and the vegetation environment of the wasteland still needs further improvement. The monthly NDVI gap of the wasteland during the growing season shows that the ratio of NDVI increasing area of most months is far greater than the NDVI decreasing area. But the decreasing area caused by the management, high temperature and draught in May and June is far greater than the increasing area. In August and September, leaves begin to fall, and the chlorophyll content decreases, so the ratio of NDVI decreasing area increases rapidly to the second peak. The species and area coverage of evergreen plants, LAI value of plants and canopy structure would influence NDVI.
Keywords: *NDVI, wasteland, vegetation coverage, unmanned aerial vehicle, multispectral, ecological restoration*

Introduction

There are numerous wastelands generated by all forms of mineral mining in China, which has caused great damage to the ecological environment (Zhou, 2021). The wastelands include several types. For instance, the wasteland polluted by heavy metals is severely hazardous; mining wasteland like quarries are not toxic, but still suffer from damaged landform, sparse or disappeared vegetation, poor soil and pose a safety hazard (Li, 2019). Chalk soil wasteland is a relatively special ore wasteland, which is free from toxic pollution but characterized by complex terrain, poor soil, sparse vegetation and severe dust pollution. At present, the ecological restoration of mining wasteland usually aims at recovering the vegetation, to build a recreational land with such functions as recreation, tourism, production, and popular education on this basis. Nanning Garden Expo adopts various methods and approaches to reconstruct the quarry landscape, such as waste-scape creation, vegetation restoration and increase of recreational facilities (Wang and Lin, 2019). Through mountain, water, forest, soil and pit belt treatment and

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restoration, an ore wasteland in Tongluo Mountain, Chongqing was reconstructed to a national mining park (Du et al., 2021). In the design of Zishan Park in Handan, in-depth research has been carried out from the landscape, network of rivers, vegetation and ecological environment (Wu et al., 2021). A mining wasteland in Tangshan was reconstructed to be an ecological park through the ecological restoration of vegetation, water body construction and other ecological measures (Huang and Guo, 2020).

Currently, vegetation restoration, soil improvement, construction of an artificial wetland with pit pond, and mining relic protection and utilization, etc. have been used for the ecological environmental treatment of the chalk soil wasteland (Zhang et al., 2006; Chang et al., 2020). Vegetation restoration is mainly measured by vegetation indexes, which includes NDVI, optimized soil adjusted vegetation index (OSAVI), green-red vegetation index (GRVI), ratio vegetation index (RVI), difference vegetation index (DVI), modified soil adjusted vegetation index (MSAVI) (Guo et al., 2020) etc., NDVI is the most widely-applied vegetation index (Fan et al., 2016). NDVI is highly correlated with leaf area index (LAI), biomass and net primary productivity, which can perfectly reflect the vegetation coverage and vegetation growth (Yuan, 2016). Luo (2019) studied the impact of NDVI time course on the vegetation restoration and climate change in the mining area with Landsat data and meteorological data. Shao (2017) analyzed the impact of mining on the vegetation coverage based on the NDVI analysis with Landsat data. Zhou et al. (2016) analyzed the loss of net primary productivity of vegetation caused by rare earth mining based on NDVI data. At present, the data source for the research on vegetation restoration of wasteland is mainly based on satellite remote sensing image, with such disadvantages as low resolution, poor timeliness, disturbance of cloud cover and high cost, which influences the accuracy of analysis to a certain extent. In recent years, UAV technology has developed rapidly, and become an important approach for obtaining the information about ecological environment safely and efficiently (Zhang et al., 2019), with a bright application prospect in the research on vegetation restoration for wastelands.

Growing season refers to the period in which plants begin to revive and turn green (beginning of the growing season) till they turn yellow and wither (end of the growing season), which is usually between March and October in Henan. Spatial information on wasteland could play an important role in urban land management (Grădinaru et al., 2019). This study attempts to use UAV carrying a multispectral camera to monitor and analyze the changes of vegetation coverage on the wasteland during the growing season in a monthly time sequence, so as to provide a basis for vegetation improvement and plant configuration of wastelands.

Materials and methods

General situation of the research area

The research area is located in Luwangfeng Village, Fengquan District, Xinxiang, Henan Province of China as shown in *Figure 1*, with a total coverage of 83.97 hectares. It is in the north of Henan Province, featuring a warm temperate continental monsoon climate, with four distinct seasons, cold winter, hot summer, cool autumn and early spring. The mean precipitation throughout the year is 573.4 mm. Fengquan District was the largest supply base of building materials in northern Henan in the last century. The chalk soil of this wasteland was used to produce cement. In 2000, it was shut down and abandoned, and treated with private capital under the guidance of the government, by

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virtue of vegetation restoration, landform utilization, landscape reconstruction and other methods. Currently, it is operated in the form of recreational agricultural sightseeing park (Wang and Zhang, 2015). The vegetation species are complicated in the par, such as nursery garden, crop plantation, orchards, vegetable gardens, lotus ponds, wetlands, landscape plants, etc.

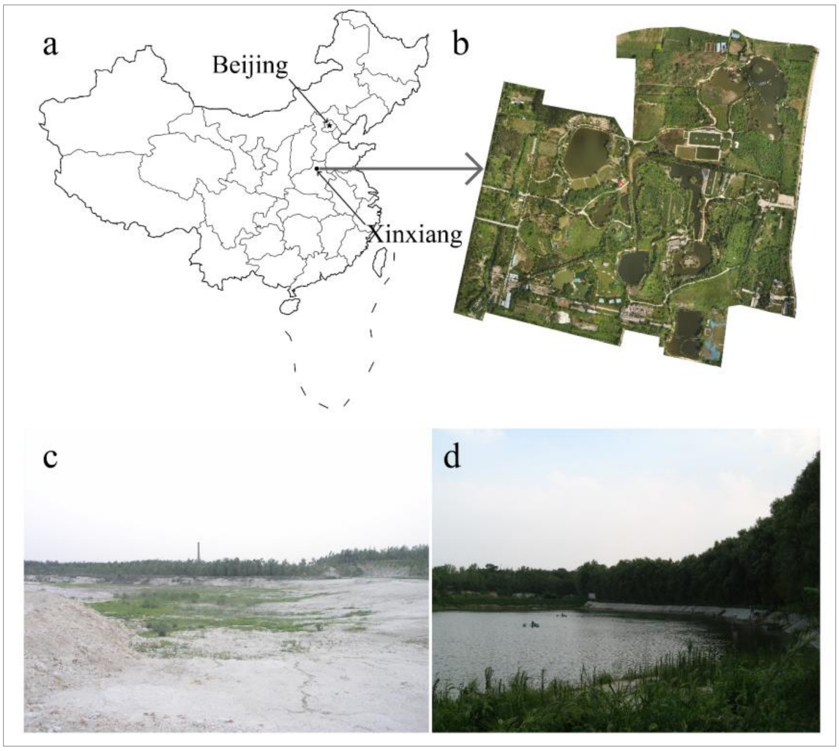

Figure 1. *Location of the study area (a); Orthographic projection of the study area (b); Ecological restoration photo of chalk wasteland in 2003 (c); Ecological restoration photo of chalk wasteland in 2020 (d)*

Data acquisition and processing

Data acquisition

Phantom 4 Multispectral was used, and its integrated multispectral imaging system combines a visible light camera and five multispectral cameras (blue light, green light, red light, red edge and near-infrared). This wasteland was photographed from March to September in 2021. To avoid the influence of the weather on UAV flight, photos were taken when there was no wind and cloud around the 25th day of each month. The same settings were used on every flight: UAV flight height was 200 m, the course overlap was 78%, the side overlap was 75%, the main route angle was 83°, the ground resolution was 10.72 cm, the flight area was 85.24 hectares, and the route length was 21028 meters. 669 photos were taken in each band.

Image pre-processing

Pix4D mapper pro was applied for single-band image stitching, to obtain the stitched images of red, blue, green, near-infrared and red edge bands. Phantom 4 multispectral

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positioning system supports the connection to D-RTK 2 high-precision GNSS mobile station and network RTK. Therefore, the images obtained have precise geographic coordinates, and there is no need for geographic registration. The multispectral light intensity sensor integrated on the top of Phantom 4 multispectral could capture the solar irradiance and record it in the image file. Solar irradiance data could be applied for compensating the illumination of the image, to eliminate the disturbance of the ambient light to data acquisition. Consequently, there is no need for atmospheric correction. ENVI 5.3 software was applied for cutting the stitched images along the boundary of the research area.

NDVI extraction and classification

NDVI extraction

NDVI is the ratio of the difference between the reflectivity of near-infrared band and red band to the sum of the two, which usually ranges between -1 and 1. Negative means the ground is covered by cloud, water, snow, etc. which can highly reflect visible lights. 0 means there is rock or bare soil, etc. NIR is approximately equivalent to R. Positive means there is vegetation coverage, and it increases with the expansion of coverage (Xu and Wang, 2021). In this research, vegetation index was studied, and the value less than 0 was zeroed. The calculation formula is as follows:

$$NDVI = \frac{NIR - R}{NIR + R} \qquad \text{(Eq.1)}$$

where: NIR represents the reflectivity of the near-infrared wave band, and R represents the reflectivity of the red light wave band.

NDVI mean value and classification

According to *Equation 1*, the mean value and monthly mean value of NDVI within the research area during the growing season were worked out, since both the mean value and monthly mean value could reflect the general vegetation coverage and monthly vegetation coverage on the wasteland.

Currently, there is no unified standard for NDVI classification. In some research, it is insisted that green vegetation ranges between 0.2 and 1 (Wang et al., 2021). Due to the extremely high resolution of UAV remote sensing image, NDVI was classified into six levels. Specifically, I level, ranging between 0 and 0.1, bared land; II level, ranging between 0.1 and 0.2, low coverage; III level, ranging between 0.2 and 0.4, middle coverage; IV level, ranging between 0.4 and 0.6, relatively high coverage; V level, ranging between 0.6 and 0.8, high coverage; VI level, ranging between 0.8 and 1.0, extremely high coverage.

NDVI difference change

The difference between the current month's NDVI and last month's NDVI can reflect coverage change in different months. NDVI increase means an increase in vegetation coverage, while NDVI decrease means a decrease in vegetation coverage.

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Result and analysis

Mean NDVI of chalk soil wasteland in the growing season

Total mean NDVI of chalk soil wasteland in the growing season

The total mean NDVI of the wasteland in the growing season is only 0.21, of middle coverage level. After almost two decades of treatment, the vegetation index is still low, because there is still a large area of bare chalk soil in the research area, which is free of plant growth or only has sparse grasses; trees and shrubs are mostly planted through local soil replacement for vegetation restoration on the wasteland, and the barren soil leads to slow growth; most planting areas have certain gentle slopes, which are not conductive to soil and water conservation and affect the water supply for plants; insufficient wasteland treatment also affects the post management.

Monthly mean NDVI of chalk soil wasteland in the growing season

According to *Table 1*, it is clear that mean NDVI is the lowest in March, and it is mainly contributed by *Cedrus deodara*, *Ligustrum lucidum*, *Sabina chinensis*, *Platycladus orientalis*, *Euonymus japonicus*, *Photinia serrulata*, *Pittosporum tobira*, *Sabina chinensis*, *Phyllostachys bambusoides* and other evergreen plants. Since April, LAI of deciduous plants increases rapidly, and mean NDVI reaches 0.3 in August, 2.5 times of that in March. The growth range of mean NDVI in April is the biggest, since plants enter the vigorous growth stage as the temperature rises gradually. The mean NDVI in June declines due to the sales of seedling, wheat crop harvesting, orchard weeding, and draught. Plant LAI still grows in July and August, so the mean value is still on the rise, but decreases rapidly after reaching the peak in August, lower than the NDVI by the end of April, since deciduous plants begin to enter the deciduous stage.

Table 1. *Monthly mean NDVI of chalk soil wasteland in the growing season*

Month	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
Monthly mean	0.12	0.21	0.25	0.21	0.27	0.30	0.18	0.16
Coverage level	II	III	III	III	III	III	II	II

NDVI level and distribution of chalk soil wasteland in the growing season

Total mean NDVI level and distribution of chalk soil wasteland in the growing season

The total mean NDVI of wasteland was classified (*Figure 2, Table 2*), in which, I level accounted for 29.66%, II level 19.03%, III level 36.44%, IV level 14.82%, V level 0.04%, and VI level 0%, indicating that about 2/3 of the area was covered by vegetation in the growing season. After nearly 2 decades of ecological restoration, the ecological environment of the park has been greatly improved, but high-coverage area still takes up a small percentage, and plants still need to be adjusted to improve the ecological environment.

Monthly NDVI level distribution of chalk soil wasteland in the growing season

According to *Table 3* and *Figure 3*, I level coverage of the wasteland was the highest. It decreased gradually from March to May, rose slightly in June, continued to decrease in July and August, rose substantially in September, and reached the peak by the end of

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October. In March, the ratio of II level to V level coverage decreased gradually, by then most plants were grasses, evergreen trees and shrubs accounted for a small percentage, and deciduous plants were in the early stage of growth. In April, the ratio of II level to IV level coverage increased gradually then dropped quickly, since trees and shrubs were in steady growth, but community coverage had not taken shape yet. In May, all kinds of plants entered prosperous stage, and the ratio of II level to IV level coverage increased gradually and then decreased, basically equal to that in April, but its V level coverage increased evidently when compared to that in April. In June, the ratio of II level to III level coverage increased slightly when compared to that in May, but its IV level and V level coverage decreased, mainly due to the high temperature and drought, and lack of rainfall in June, which resulted in the death or decay of plants. The rainfall was ample in July and August. In July, II level coverage decreased slightly when compared to that in June, but III level and IV level coverage increased evidently. In August, II level to IV level coverage was almost the same as that in July or increased slightly, but V level coverage was 2.18 times of that in July. In September, the ratio of II level and III level coverage increased when compared to that in August, but IV level and V level coverage decreased evidently. By the end of October, I level coverage exceeded 50%, while other levels were the same as that by the end of September or decreased slightly. At this moment, the chlorophyll content of some deciduous plants decreased, and a few plants began to enter the deciduous period.

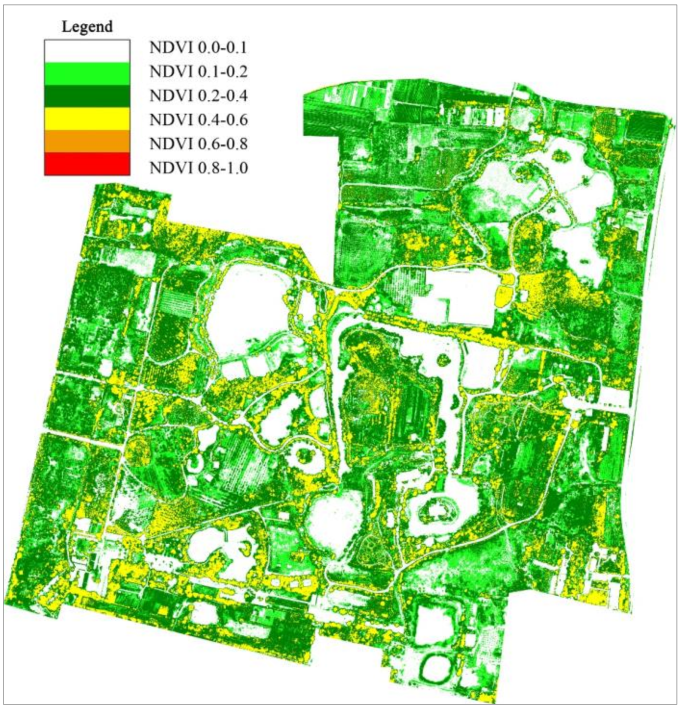

***Figure 2.** Levels of the total mean NDVI of the chalk soil wasteland in the growing season*

***Table 2.** Total mean NDVI level distribution of the chalk soil wasteland in the growing season*

Coverage level	I	II	III	IV	V	VI
Percentage (%)	29.66	19.03	36.44	14.82	0.04	0.00

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Table 3. *Monthly NDVI level distribution of chalk soil wasteland in the growing season*

	Mar. (%)	Apr. (%)	May (%)	Jun. (%)	Jul. (%)	Aug. (%)	Sep. (%)	Oct. (%)
I	56.58	46.45	39.19	43.67	34.95	31.64	44.62	50.27
II	23.12	8.62	10.35	11.81	5.78	5.88	12.88	12.92
III	13.1	18.28	17.97	19.46	21.72	20.11	28.52	23.61
IV	5.76	23.15	23.78	21.13	34.12	35.01	13.66	12.63
V	1.43	3.50	8.69	3.92	3.37	7.33	0.27	0.58
VI	0.00	0.00	0.01	0.01	0.06	0.03	0.03	0.00

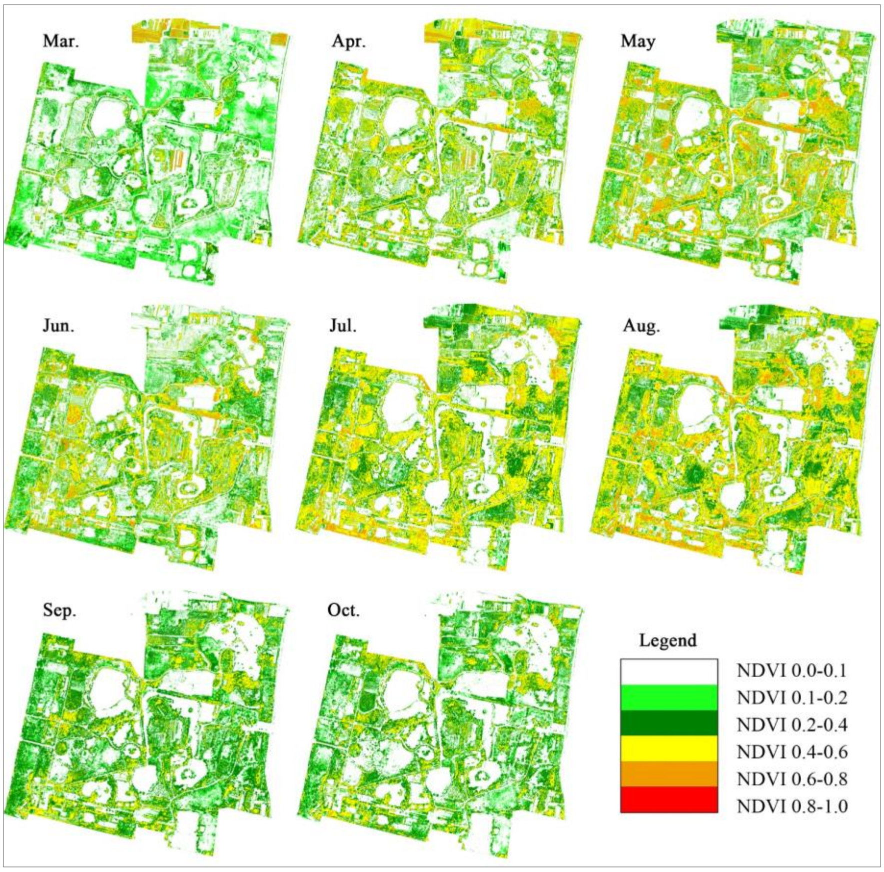

Figure 3. *Diagram of monthly NDVI level distribution of chalk soil wasteland in the growing season*

Monthly NDVI difference of chalk soil wasteland in the growing season

According to *Table 4* and *Figure 4*, NDVI of the wasteland in the growing season was always in dynamic changes. Generally, NDVI increasing area between March and April and between April and May was far greater than the decreasing area. Especially in April and May, due to the fast growth of plants, the increasing area reached the maximum 55.3%, the first peak. The NDVI decreasing area in May and June was far greater than the increasing area, reached the first peak, mainly due to the sales and transplanting of seedlings. For instance, after the transplanting of privet nursery in the southwest of the park, NDVI dropped rapidly. In addition, the wheat harvesting, Orchard weeding and

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other management activities also led to the decrease of NDVI. But the primary reason shall be drought and little rain. In June in Xinxiang, there were 16 days with the highest temperature above 35℃, and 6 days with the highest temperature above 37℃. In days of high temperature, the moisture of soil lost quickly, and the poor irrigation condition led to prominent draught. With the increase of rainfall, NDVI increasing area in June to July and July to August increased rapidly and reached the second peak by the end of August. By the end of August to September, plants entered deciduous period, the chlorophyll content decreased, NDVI decreasing area increased rapidly to the second peak, and only a few areas were growing. By the end of September to October, NDVI decreasing area was still greater than the increasing area, but there were still some areas in growing state. The area of unchanged NDVI was relatively stable, since it was mainly waste bare land, road and water.

Table 4. *Monthly NDVI difference of the wasteland in the growing season*

	Percentage of NDVI decreasing area (%)	Percentage of NDVI unchanging area (%)	Percentage of NDVI increasing area (%)
Mar. – Apr.	32.34	19.50	48.16
Apr. – May	22.23	22.47	55.30
May – Jun.	54.30	20.98	24.72
Jun. – Jul.	33.25	19.53	47.22
Jul. – Aug.	25.90	23.96	50.14
Aug. – Sep.	68.24	23.36	8.40
Sep. – Oct.	40.16	31.21	28.63

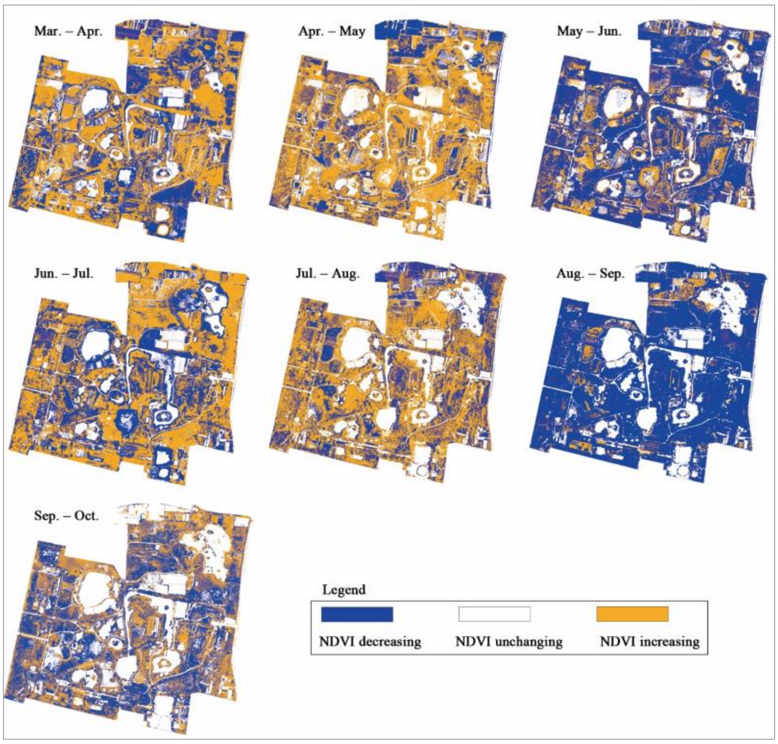

Figure 4. *Distribution diagram of monthly NDVI difference of the wasteland in the growing season*

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Discussion

Impact of evergreen vegetation on NDVI

The vegetation of chalk soil wasteland entered the growth stage in March, and at this moment, NDVI basically reflected the coverage in winter. The dust pollution was relatively severe in winter, especially in windy days, the dust pollution had caused a great disturbance to surrounding residents. The low ratio of evergreen plants on the wasteland led to a poor dust retention effect in winter (Yin et al., 2020). The research showed that the dust retention capability of plants was impacted by the density, size, roughness and dip angle of leaves, but it generally had a good dust retention effect. The dust retention performance of different plants is ranked as follows: Coniferous tree > shrub > broadleaved tree > herbs and vines. In northern China, coniferous trees with rough leaves and secreting mucus is a reasonable choice (Liu et al., 2021). According to the research results of Li et al. (2021), *Cedrus deodara, Sabina chinensis, Photinia serrulata, Nerium oleander, Eriobotrya japonica* and other plants can be taken into account. Due to the impact of vegetation distribution zone, deciduous plants usually account for a large proportion in the landscape design in Northern Henan, but due to the particularity of wasteland transformation, so priority shall be given to ecological benefits. In order to make up for the shortcomings of low NDVI and poor ecological benefits in winter, the planting ratio of evergreen plants in the wasteland should be further increased, and evergreen plants could be planted on bare lands, and the ratio could even exceed 50%. In addition, the large area of bare land and the single species of evergreen plants usually lead to poor visual effect. In order to improve NDVI in winter, it is necessary to increase the species of evergreen plants and increase the planting ratio, so as to better play the ecological service function.

Impact of plant LAI on NDVI in the growing season

One of the reasons why the NDVI of wasteland is at a low level shall be the low LAI of some plants. LAI is an important structural parameter in the land surface process, as well as one of the most fundamental parameters to characterize the canopy structure of vegetation (Cai and Sha, 2019). Generally, the higher LAI the better the ecological benefits. It is of great significance to take LAI-based green volume ratio as the index to measure the greening ratio of the city (Li et al., 2004). Currently, the index has not been widely used, since it is difficult to be determined. Due to the different growth regions and environments, LAI of the same plant may vary greatly. In different studies, the relationship between LAI and NDVI may be linear or non-linear, but there is a positive correlation between LAI and NDVI, namely, the higher the leaf area index, the higher NDVI (Sun et al., 2021). The main reason is that when the plant LAI is high, the clearance of the leaves decreases and the covering effect on the ground is enhanced in the vertical projection.

According to the dynamic tracking of LAI of major green plants in Xinxiang by Zhang et al. (2017), there were certain rules for the leaf area index of adult plants growing in the same area, and LAI interval calibration could be conducted through mass sampling. The LAI of *Cedrus deodara*, *Juniperus chinensis*, *Ligustrum lucidum*, *Pyrus betulifolia*, *Aesculus chinensis*, *Eucommia ulmoides*, *Ailanthus altissima*, *Chaenomeles sinensis*, *Eugenia caryophllata*, *Prunus cerasifera*, *Eriobotrya japonica*, *Photinia serrulata*, *Hibiscus syriacus*, *Prunus persica*, *Chimonanthus praecox*, *Lonicera maackii*, *Punica granatum*, *Sabina chinensis*, *Platycladus orientalis*, *Viburnum odoratissimum*,

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Phyllostachys bambusoides and other plants is relatively high in Xinxiang, while that of *Albizia julibrissin*, *Salix babylonica*, *Ailanthus altissima*, *Acer pictum*, *Sapium sebiferum*, *Salix matsudana*, and *Melia azedarach* is relatively low. Therefore, plants with higher LAI should be selected as the main tree species for the plant configuration optimization of this wasteland, while plants with lower LAI can be used as matching tree species to increase the NDVI and enhance the species diversity and ornamental properties. Of course, it is necessary to test planting in advance to test the adaptability of plants to site conditions.

Impact of the canopy configuration on the NDVI in the growing season

Improving the canopy structure of vegetation is an important measure to increase NDVI. There are mainly four types vegetation canopy structure: single-layer loose type, single-layer closed type, multi-layer loose type and multi-layer closed type. Pure forests, trees, shrubs and grasses are mainly adopted for the vegetation restoration of this wasteland, which is dense in the plane but simple in the façade (Li et al., 2015). Although it is relatively dense in horizontal layout, but the main canopy structure is single-layer loose and multi-layer loose type. The single-layer closed type accounts for a small proportion, while the multi-layer closed type only appears in a few areas. Therefore, the plant restoration in this wasteland should be further optimized, and a community structure with compact horizontal distribution and rich vertical structure can be formed as much as possible, and high-density, multi-level complex communities can be formed where possible. In terms of specific methods, the density can be increased in horizontal distribution and layers can be added for the vertical distribution. But it is worth noting that during vegetation arrangement, higher LAI may not be better. The plants' needs for light, ventilation and nutrients shall be taken into account for the shaping of artificial plant layers, and further research is needed to establish a more stable plant community.

Conclusions

Through the research on chalk soil wasteland, the following conclusions can be drawn:

(1) After nearly two decades of treatment, the ecological environment of the wasteland has been remarkably improved, but it is still of middle coverage level. The monthly mean NDVI of wasteland in the growing season ranges between 0.12 and 0.3, of middle coverage level and levels below.

(2) The monthly NDVI level distribution of the wasteland in the growing season shows that the high vegetation coverage ratio is relatively low, and the vegetation environment of the wasteland still needs to be greatly improved and enhanced. The monthly NDVI difference of the wasteland indicates that operation and extreme weather have a significant impact on NDVI.

(3) UAV remote sensing can be effectively applied for the rapid image acquisition of ecological environment of the chalk soil wasteland, and it can provide high-quality vegetation index information and scientific basis for the optimization of ecological environment after data processing and analysis. UAV multispectral image features a fast speed, low cost and high precision when being applied for monitoring the changes of vegetation coverage of chalk soil wasteland, and it is suitable to be promoted and applied for the treatment of ecological environment for wastelands.

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It is an important direction in future to conduct more in-depth research on the NDVI data obtained by UAV and the vegetation data obtained from ground surveys to provide a scientific basis for the ecological restoration of chalk soil wasteland.

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REFERENCES

[1] Cai, W. J., Sha, J. M. (2019): Inversion of leaf area index based on geographical environment factors. – Journal of Subtropical Resources and Environment 14(2): 55-64.

[2] Chang, J., Li, C. K., Song, Y. C. (2020): Research progress on landscape reconstruction of mining wasteland in China. – Chinese and Foreign Buildings 9: 63-66.

[3] Du, Y. C., Xiong, C., Duan, Y., Yu, M., Li, J. H. (2021): Landscape planning and design of Chongqing Causeway Mountain National Mine Park based on ecological restoration. – Southern Agriculture 15(16): 16-22.

[4] Fan, D. Q., Zhao, X. S., Zhu, W. Q., Zheng, Z. T. (2016): Review of influencing factors of accuracy of plant phenology monitoring based on remote sensing data. – Progress in Geography 35(3): 304-319.

[5] Grădinaru, S. R., Kienast, F., Psomas, A. (2019): Using multi-seasonal Landsat imagery for rapid identification of abandoned land in areas affected by urban sprawl. – Ecological Indicators 96(2): 79-86.

[6] Guo, Y. K., Liu, J. Q., Guo, Y. Q., Cao, X., Xie, Q. (2020): GLIBERTY-DSAIL coupled model inversion of vegetation LAI in southern mixed forest LAI. – Bulletin of Surveying and Mapping 11: 39-42, 75.

[7] Hu, Z H. (2020): Remote sensing monitoring of Lingling Manganese Mine Restoration Project based on timing NDVI. – Chinese High and New Technology 13: 117-118.

[8] Huang, H., Guo, S. M. (2020): From "Ugly Chaos"to "Picture-pictured" landscape art improvement design of waste land in coal mine industry - A case study of Nanhu Park in Tangshan. – Architecture and Culture 1: 128-129.

[9] Li, F., Wang, R. S., Juergen, P. (2004): Research on green space ecological concept planning in Beijing. – Urban Planning Transactions 4: 61-64, 96.

[10] Li, L., Zhou, G., Yao, C. H. (2015): Study on the green volume of different types of urban green spaces. – Chinese Landscape Architecture 31(9): 17-21.

[11] Li, X. J. (2019): Landscape regeneration design of abandoned mining land from the perspective of aesthetic value - A case study of Huairou Open-pit mine in Beijing. – Southwest Jiaotong University, Dissertation.

[12] Li, C. M., Wang, J. M., Wang, T. F., Wang, Z. X., Lei, Y. K., He, D. (2021): Dust-retention capability and leaf traits of common park greening plant species in Zhengzhou City. – Journal of Northwest Forestry University 36(2): 123-129.

[13] Liu, W. H., Li, W. W., Pei, S. X., Li, X. G. (2021): Analysis on the dust-retention ability of common garden plants in China. – Forestry and Ecological Sciences 36(3): 328-336.

[14] Luo, J. W. (2019): The result analysis of the vegetation restoration effect of rare earth tailings based on NDVI and object spectral characteristic. – Nanchang Institute of Technology, Dissertation.

[15] Shao, Y. P. (2017): Study on dynamic monitoring and vegetation coverage of rare earth mines. – China University of Geosciences (Beijing), Dissertation.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2004_33113322

[16] Sun, Y., Gu, Z. J., Li, D. L. (2021): Study on remote sensing retrieval of leaf area index based on unmanned aerial vehicle and satellite image. – Science of Surveying and Mapping 46(2): 106-112, 145.

[17] Wang, J. P., Zhang, Y. C. (2015): From wasteland to the wonderful land: the ecological restoration and landscape reconstruction of chalk mine land in suburb. – Chinese Landscape Architecture 31(4): 20-24.

[18] Wang, X. R., Lin, Q. (2019): The revealing and reconstitution of landscape - Quarry Gardens in Nanning Garden Expo Park. – Chinese Landscape Architecture 35(7): 24-33.

[19] Wang, D., Zhao, P., Sun, J. B., Niu, L. Y., Liu, B. F. (2021): Inversion of chlorophyll content in summer maize based on UAV multi-spectrum. – Shandong Agricultural Sciences 53(6): 121-126, 132.

[20] Wu, X. M., Kang, Y., Xiao, H. J., Yang, T. (2021): Elastic shaping of water ecology in abandoned mine - the design practice of Zishan Park in Handan City. – Chinese Landscape Architecture 37(6): 105-110.

[21] Xu, J. H., Wang, S. D. (2021): Spatio temporal analysis of vegetation cover in mining city - A case study of Xuzhou city. – GrassLand and Turf 41(3): 91-98.

[22] Yin, Z. J., Shen, X. X., Li, R. L., Gao, H. H., Yu, L. Y., Zhou, L., Wu, H. L., Cao, Y. (2020): Study on the dust retention effect of common garden plants in Shenzhen. – Acta Scientiarum Naturalium Universitatis Pekinensis 56(6): 1081-1090.

[23] Yuan, M. X., Zou, L., Lin, A. W., Zhu, H. J. (2016): Analyzing dynamic vegetation change and response to climatic factors in Hubei Province, China. – Acta Ecologica Sinica 36(17): 5315-5323.

[24] Zhang, Y. C., Qiao, L. F., Zhao, Y. P., Yao, L. F. (2006): The study of the potential values of abandoned land in suburb - Takes the Shili Agricultural Ecological Park as an example. – Research of Soil and Water Conservation 6: 94-96.

[25] Zhang, Y. C. (2017): Rainwater characteristics and optimization of typical green space under sponge city-oriented - Take Xinxiang City as an example. – Wuhan University, Dissertation.

[26] Zhang, M. X., Mei, D. Y., Gao, W. J., Bao, Q. X., Li, F. Z. (2019): Review on the applications of UAV remote sensing technology to urban green space monitoring. – Journal of Chinese Urban Forestry 7(5): 5-11.

[27] Zhou, X. F., Zhu, W. Q., Ma, G. X., Zhang, D. H., Zheng, Z. T. (2016): Assessing the vegetation net productivity loss resulted from the mining of rare earth ore based on remote sensing technology - A case study in Ganzhou, Jiangxi Province. – Remote Sensing Technology and Application 31(2): 307-315.

[28] Zhou, P. F., Zhang, S. W., Luo, M., Wei, H. B., Song, Q., Fang, B., Zhuang, H. J., Chen, H. Y. (2022): Characteristics of plant diversity and heavy metal enrichment and migration under different ecological restoration modes in abandoned mining areas. – Environmental Science 43(2): 985-994.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2004_33113322