Environmental aspects of remote sensing for the classification of asbestos industry impact on the landscape changes in Cyprus

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Abstract

The Industrial Revolution led to the commercial exploitation of asbestos in Cyprus. Cyprus has the second largest asbestos deposits in Europe, after Italy. Even though most of the extracted asbestos was exported, Cyprus had two operational asbestos manufacturing plants. Production increased steadily until 1980, with mining activities ending in 1988. These activities have left a significant mark on the environment. The key example of post-asbestos landscape in Cyprus is the opencast mine at Amiandos in the Limassol District, where large amounts of asbestos were mined. This has had a considerable impact on the natural environment and land use including the disposal of asbestos residues and asbestos-cement waste. Temporal analysis of land use changes from 1963 to 2014 reveals shifts in exploitation areas and vegetation cover. Though challenges persist, including asbestos-containing waste, efforts to restore vegetation in the mine area are evident. The evolution from sparse and undeveloped vegetation to a lush and diverse ecosystem is important for restoring ecological balance and restoring habitats for local fauna and flora. This research provides critical insights into the historical context, environmental impacts, and remediation efforts related to asbestos mining in Cyprus.

1. Introduction

Asbestos refers to the fibrous minerals from the serpentine and amphibole groups, which are found in various forms worldwide (Hendry, 1965). Nowadays asbestos is a commercial designation for a collection of mineral products known for their high tensile strength, flexibility, resistance to chemical and thermal breakdown, and excellent electrical insulation properties, and can be woven (Murray, 1990).

During the Byzantine period, chrysotile fibre composites were incorporated into the final plaster layer of a 12th-century wall painting at the Monastery of Saint Neophytos (Kakoulli et al., 2014). Additionally, surface findings in the Paphos region indicate that asbestos was utilized locally for crafting bowls and decorative figures (Xenophontos, 1991). The commercial use of asbestos in Cyprus was brought about by the Industrial Revolution driven by the development of a method of manufacturing asbestos-cement flat and corrugated sheets, which resulted in a significant increase in demand for asbestos-containing products (Rosato, 1959). During World War II, asbestos was predominantly utilized for military applications (Craighead, 2008). Following the war, the demand for asbestos significantly surpassed its supply. This global surge led to the widespread production of asbestos-cement products (Virta, 2002).

The adverse health effects of asbestos were first documented in medical literature during the 1930s (Murray, 1990). The International Agency for Research on Cancer, part of the World Health Organization, has classified asbestos as a carcinogen (IARC, 1977). The World Health Organization's environmental health criteria emphasize that all types of asbestos fibres are associated with diffuse pulmonary fibrosis (asbestosis), bronchial carcinoma, primary malignant tumours of the pleura and peritoneum (mesothelioma), and various other cancers (WHO, 1986). In response to international recommendations, 67 countries, including 34 in Europe, have banned asbestos use (IBAS, 2022). The European Union, through Commission Directive 1999/77/EC of July 26, 1999, set a deadline of January 1, 2005, for the prohibition of chrysotile use, with one minor exception.

Cyprus had the second largest asbestos deposits in Europe, following Italy, and it contains the oldest known mines where chrysotile asbestos was especially significant (Rosato, 1959). Asbestos fibres are found in the serpentines of the Troodos Mountains in the island's centre and the Akamas Peninsula in the west. The asbestos reserves were projected to last for 200 years (West and Schreck, 1962).

The asbestos mine located in the Troodos Mountains was opencast (Bowles, 1959). Asbestos fibres were second in value of production in the mineral industry of Cyprus (Houk and Barsigian, 1949). Even though most of the mined asbestos was exported (Virta, 2006), Cyprus had two operational asbestos manufacturing plants (Maliotis, 2021). Production started in 1907, increased steadily until 1980, and ceased operations in 1988.

Mining activities have left a significant impact on the landscape and environment (Oldfield and Dearing, 2003). The post-asbestos landscape is present in the opencast mine at Amiandos in the Limassol District, where large quantities of asbestos were extracted. This has affected the natural environment through mining operations and altered land use patterns, including the development of new settlements for mine workers and their families.

Abandoned in 1988, the mine embodies eighty years of Cyprus' mining industry history and its journey toward industrialization. Despite asbestos-related environmental challenges, ongoing efforts to restore the area overlook its cultural significance. Consequently, there is a concern that the distinct attributes defining the area's identity may gradually vanish. The objective of this paper is to identify the influence of the asbestos industry in Cyprus having an aesthetic, natural, and cultural influence on landscape change. The motivation behind the survey is to comprehend the effects of historical asbestos extraction and usage on the landscape, as well as their current impact on the environment in Cyprus.

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2. Materials and methods

2.1 Study area

Cyprus, the third largest island in the Mediterranean Sea, is situated near the Middle East region and has been a member of the European Union since 2004. Administratively, the Republic of Cyprus is segmented into six districts: Lefkosia, Famagusta, Kyrenia, Larnaca, Lemesos, and Paphos (Figure 1).

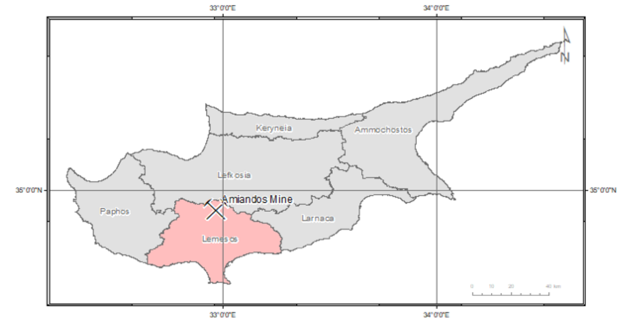

Figure 1. Study area.

2.2 Data gathering

Primary data were obtained from in-situ surveys, direct observations, and interviews regarding factors influencing landscape changes in Cyprus and the prevalence of asbestos-cement roofs. In-situ surveys and direct observations were conducted in the areas of the Limassol (Lemesos) district and the Amiandos mine, in October 2022. Geospatial data on land use changes in the asbestos mine, the location of asbestos-cement roofs, and descriptive characteristics were collected through field surveys, direct observations, and interviews.

Spatial changes in the Amiandos mine were assessed using spatial data provided by the Department of Lands and Surveys of the Ministry of Interior of the Republic of Cyprus, in compliance with Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007, which establishes an Infrastructure for Spatial Information in the European Community (INSPIRE). Aerial imagery from 1963, 1994, and 2014, with a spatial resolution of 50 cm and three spectral channels (RGB), was used in the survey.

Sentinel is a series of observation satellites that deliver high-resolution multispectral images, facilitating the analysis of various environmental parameters, including vegetation (Copernicus Data Space Ecosystem, 2024). The Sentinel-2 L2A (S2L2A) data collection with applied atmospheric correction were used for the analysis of remote sensing indicators for monitoring changes in vegetation. The initial phase involved acquiring the Sentinel-2 L2A (S2L2A) dataset with the atmospheric correction at four-year intervals. The datasets used, each with a spatial resolution of 10 meters, were:
(a) 2015, acquired on August 13,
(b) 2019, acquired on August 12,
(c) 2023, acquired on August 16.

2.3 Data analysis

Spatial and temporal change analyses were conducted using a land use transfer matrix (Briassoulis, 2020) to identify variations in different land use types within the Amiandos mine area. These variations are depicted in the land use transfer matrix (1) below:

$$L_{ij} = \begin{bmatrix} L_{11} & \cdots & L_{1t} \\ \vdots & \ddots & \vdots \\ L_{1t} & \cdots & L_{tt} \end{bmatrix} \quad (1)$$

where: L is the land use type area,
t is the land use type,
i and j are the land use types at the beginning and end of the research period, respectively.

The normalized difference vegetation index (NDVI) is extensively utilized in vegetation growth studies to identify vegetation and assess overall plant health. NDVI was computed using the following equation (2):

$$NDVI = \frac{Band\ 8 - Band\ 4}{Band\ 8 + Band\ 4} \quad (2)$$

where: Band8 represents the reflectance value of the near-infrared band
Band4 represents the reflectance value of the red band

NDVI values are normalized to a range between -1 and 1. High NDVI values denote dense and healthy vegetation, whereas low values (0–0.4) may indicate sparse or absent vegetation (0–0.2) or vegetation in poor condition (0.2–0.4).

Pre-trained Convolutional neural networks (CNN) models from the Keras library (Chollet, 2015) and TensorFlow packages were employed for the recognition of asbestos-cement roofing. The experiments were conducted in a TensorFlow 2.10 environment using the Keras library, which is renowned for its predefined and pre-trained neural network models. Estimates were based on aerial imagery of Berengaria Village in Limassol, where waste from dismantled buildings is stored in the former mine. The aerial imagery, obtained by the Department of Lands and Surveys of the Ministry of Interior of the Republic of Cyprus in 2010, had a spatial resolution of 50 cm. A signature database for training was created using a window size of 128 by 128 pixels. These image signatures were normalized and then randomly split into a 2:1 ratio, with two-thirds used for training and one-third for validation. Machine learning was conducted using architectures from the Keras library, including DenseNet121, InceptionV3, and EfficientNetV2B1 (Keras, 2024). Each model was trained for 50 epochs with a batch size of 32 samples. The Adam optimizer was used during training, with binary cross-entropy as the loss function. Accuracy assessment was performed during validation, and overall accuracy was calculated as the ratio of correctly classified cases to the total number of cases in the test set.

3. Results

The asbestos mine in Cyprus operated in the Troodos Mountains, northwest of Kato Amiandos village in the Limassol District (Figure 1). Positioned within the heart of the Troodos Forest (Figure 2), the mine contained deposits of chrysotile. The asbestos appeared in a complex network of veins, characterized by high tensile fibres averaging 0.25 inches in length. These greenish-white fibres exhibited a silky lustre (Sagui, 1925).

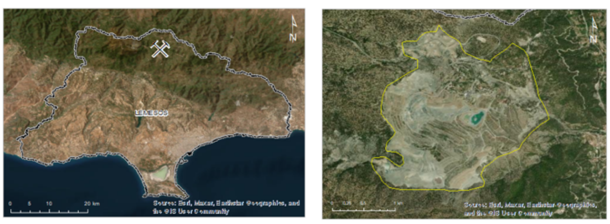

Figure 2. The Amiandos Mine area in the Troodos Mountains (Limassol District).

The environmental impact of asbestos mining activities in Cyprus has been examined, with a focus on land use changes, and the current preservation state of the Amiandos Mine area. Exports played a crucial role in the development of the asbestos industry in Cyprus (Virta, 2006). Approximately 97% of the total asbestos fibre production was destined for export markets (Figure 3).

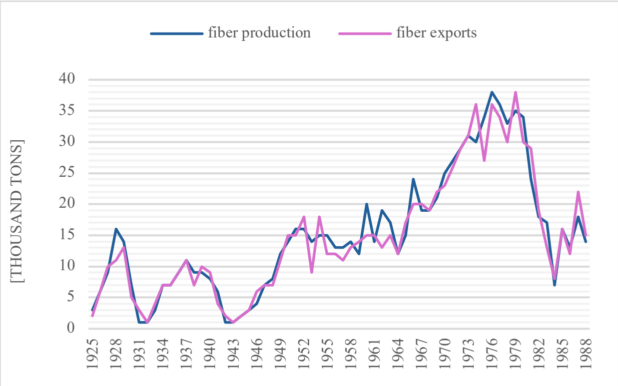

Figure 3. Asbestos fibres production and exports.

In 1988, the exploitation of the asbestos deposit concluded, and mining operations were terminated (The Mines Service, 2022). In 1992, the Cypriot Council of Ministers decided to revoke the concession for the exploitation of the deposit and initiated reclamation efforts at the mine site (Report, 2005).

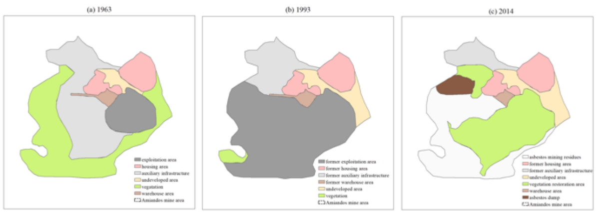

Figure 4. Land use changes in the Amiandos Mine area in 1963-2014.

Temporal analysis of land use changes from 1963 to 2014 reveals shifts in exploitation areas and vegetation cover. Though challenges persist, including asbestos-containing waste, efforts to restore vegetation in the mine area are evident (Table 1).

landuse type	area [km^2]			change [km^2]	change [km^2]
	1963	1993	2014	1993-1963	2014-1993
housing area	0.45	0.45	0.45	0.00	0.00
exploitation area	0.51	2.61	1.36	2.11	-1.26
warehouse area	0.08	0.08	0.05	0.00	-0.03
vegetation	1.54	0.07	1.45	-1.47	1.38
auxiliary infrastructure	1.42	0.61	0.33	-0.81	-0.29
undeveloped area	0.12	0.29	0.31	0.17	0.03
asbestos dump	0.00	0.00	0.17	0.00	0.17

Table 1. Change in land use types in the Amiandos mine area between 1963 and 2014.

Changes in land use types in the Amiandos mine area in the period of 1963-2014 (Figure 4) showed that the housing area remained at the same level, however, there were fewer buildings in 1993 than in 1963, and in 2014 that area was abandoned with decaying buildings in Pano Amiandos village, constructed at the mine area (Figure 5a-b). The exploitation area increased due to the increase in asbestos fibres production at the expense of the area of vegetation. In 2014 actions taken to regenerate vegetation in the mine are visible (Figure 4).

Figure 5. Remnants of buildings in Pano Amiandos village.

The reforestation of the area is visible in land cover changes, and the NDVI values achieved result from this process of revegetation. The Sentinel data were analysed to identify areas where changes in NDVI values indicate environmental restoration through vegetation growth on former mine remnants (Figure 6). However, in the initial stages of this process, low NDVI values are observed due to the absence of sparse vegetation and undeveloped ecosystems. Rare vegetation in such areas may result from difficulties in establishing plants and the slow process of ecological succession. Despite this, as time passes and the restoration process progresses, NDVI values typically begin to increase, reflecting a gradual return to healthy and diverse vegetation. This evolution from sparse and undeveloped vegetation to a lush and diverse ecosystem is important for restoring ecological balance and restoring habitats for local fauna and flora. An in-situ assessment corroborates that diminished NDVI values can signify the existence of non-vegetated features such as rocks, bodies of water, or barren terrain within the examined vicinity.

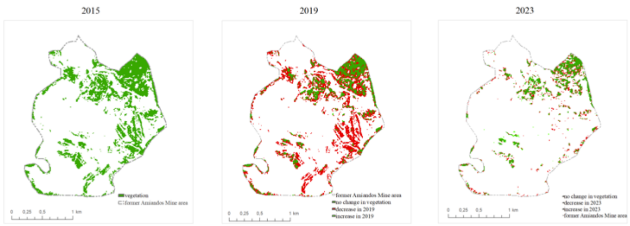

Figure 6. The presence of vegetation in the areas of the former Amiandos asbestos mine (a) 2015, (b) 2019, (c) 2023.

Restoration work commenced in 1995, focusing on stabilizing the waste dumps and reforesting the area (Figure 7). A crucial aspect of this process is restoring the area's original land use and repurposing existing structures, such as establishing the Troodos Geopark headquarters (Figure 8 a-b) or creating a botanical garden.

Figure 7. The present state of the Amiandos Mine area.

Figure 8. New functions are assigned to the former mine area.

However, most of the mined asbestos fibres were exported, with only small quantities utilized for producing asbestos-cement products in Cyprus. Asbestos-cement sheets were primarily employed as roofing materials for production facilities, warehouses, and shed buildings (Figure 9 a-b). Many of these structures remain unused today. Idle factories and abandoned industrial plants pose significant health and environmental risks, as the asbestos-containing materials used in their construction can deteriorate and release hazardous fibres into the air.

Figure 9. Examples of asbestos-cement roofing used in Limassol District.

Given that asbestos-cement sheets are still in use as roofing materials and asbestos-containing waste is deposited in the former mine basin, neural networks were utilized to estimate the potential waste quantity in one of the districts of Limassol, namely Berengaria.

Convolutional neural network (CNN) models were employed to estimate the quantity of asbestos-containing waste in the mine area. NDVI variability analysis highlights the progression of revegetation efforts over time. The examination of the operation of an asbestos-cement factory and the application of asbestos-cement products in roofing and construction indicates that asbestos-cement sheets are predominantly found in abandoned and post-production buildings, contributing to environmental pollution and posing a threat to human health.

The possibility of the estimation of the amount of hazardous waste containing asbestos was examined through the classification of asbestos-cement roofs. The following pre-trained architectures from the Keras applications libraries were tested: DenseNet121, InceptionV3 or EfficientNetV2B1, which were trained on a set of previously prepared image signatures divided into 2 classes: asbestos roofs and non-asbestos roofs. Best models were computed (Table 2).

architecture	accuracy
DenseNet121	0.7767
InceptionV3	0.6521
EfficientNetV2B1	0.7695

Table 2. Accuracy results for asbestos-cement roofing classification.

The obtained accuracies were about 0.65 to 0.77 and they suggest the importance of further investigating the potential application of these networks in identifying asbestos-cement roofs in different regions.

Through photo interpretation and field inventory of asbestos-cement roofs, it was estimated that approximately 2,300 tons of asbestos-containing waste had been removed. However, the classification of orthophotomaps using pre-trained architectures from the Keras application libraries revealed that this estimate was approximately 945 tons lower than the actual amount.

4. Discussion

The development of the asbestos mining industry has significantly altered the landscape of the town of Kato Amiandos and the surrounding Troodos Mountains. Initially characterized by small-scale mining, the area evolved into a complex comprising industrial and production facilities, along with residential quarters for mine employees and their families. The current state of the town and the former mine serves as a case study of how the cessation of open-pit mining impacts the landscape, social dynamics, and public health.

Open-pit mining operations brought profound changes to the landscape. The forest was cleared, soil removed, and all forms of natural life eradicated. The most severe environmental issue was the creation of a large crater in the quarry area, extensive rubble piles on steep slopes and in valleys, and the contamination of surface waters and dam catchments with asbestos fibres, posing risks to public health and safety (Poyiadji et al., 2018). Environmental and safety issues included altered landscapes, disused basins, land unfit for primary use due to topsoil loss, abandoned material processing landfills, changes in groundwater regimes, area contamination, subsidence, and shifts in vegetation.

Transitioning the former open pit mine area towards renewed landscape and land use presents a complex challenge for local governance. The reclamation and subsequent revegetation of the previously exploited mining site is a prolonged endeavour characterized by distinct phases of ecological succession. The initial stages feature sparse vegetation cover and rudimentary ecosystem development, reflected in low NDVI values (Hu et al., 2022). Early plant species face harsh conditions and poor soil quality, leading to gradual ecosystem recovery over time. As ecological processes unfold and plant communities establish, NDVI values increase, indicating a resurgence of vegetation and biodiversity. This shift from initial, undeveloped vegetation to thriving, diverse ecosystems underscore the importance of habitat restoration initiatives and enhancing ecological resilience.

Furthermore, recognizing the broader impacts of environmental changes resulting from the transformation of former mining areas is crucial. The shift in land use and alterations in natural landscape features require comprehensive planning and management strategies to prevent environmental degradation, maintain ecosystem functions, and protect the well-being of local communities. This complex relationship between ecological processes, land reclamation efforts, and landscape changes emphasizes the interconnectedness of human activities and environmental sustainability.

In 1995, the Ministry of Agriculture, Natural Resources, and the Environment of the Republic of Cyprus initiated a long-term restoration project titled "Biodiversity Conservation in Restoration and Management of the Amiantos Asbestos Mine, in Troodos National Forest Park." This project focuses on ensuring heap stability, mitigating health risks associated with asbestos fibers, and restoring the site to its natural forested state. The primary objective is to reestablish natural vegetation cover (MANRE, 2022).

Conversely, the restoration of the former Amiandos mine is expected to reduce the pollution risk associated with asbestos, thereby mitigating environmental asbestos exposure and enhancing public health protection (Constantopoulos, 2008; Farazi, 2014). Given that previous surveys indicate an underestimation of the environmental asbestos exposure (Wilk and Krówczyńska, 2021), further investigation is warranted in the Amiandos mine area. In 2005, the former mine site was designated as part of the Natura 2000 European Ecological Network Special Protection Areas. Additionally, since 2015, this area has been included in the Troodos Geopark, one of the Global UNESCO Geoparks, which focuses on the protection, education, and sustainable development of sites and landscapes (UNESCO, 2022).

The process of asbestos roof removal necessitates the storage of asbestos-containing waste and the appropriate preparation of landfill sites. Asbestos-containing materials, such as roof tiles and boards, must be safely removed and secured to prevent further dispersion of asbestos fibers. Properly designed and secured asbestos waste landfills are essential to minimize the risk of environmental contamination.

Estimating the potential amount of asbestos-containing waste is a crucial step in planning the removal and storage process (Wilk et al., 2015; Wilk et al., 2019). In this study, pre-trained models from the Keras library were utilized to classify and estimate the waste generated from the dismantling of Berengaria Village, which was stored in the Amiandos mine basin. Despite the low quality of the orthophotomap used for obtaining image signatures, the relatively small area, and the limited number of signatures involved in the training and evaluation processes, all tested models demonstrated the potential to distinguish between different types of roofs, albeit with varying levels of accuracy. The improved classification accuracy achieved by convolutional neural networks for recognizing asbestos-cement roofs (Krówczyńska et al., 2020; Raczko et al., 2022) underscores the need for further investigation into the application of these networks for identifying asbestos-cement roofs in different regions.

This analysis facilitates effective management of asbestos-containing waste and considers critical aspects related to environmental impact, land use, and environmental protection. By employing advanced image processing techniques, the identification of asbestos-cement roof coverings and the estimation of waste amounts become more precise and efficient (Krówczyńska and Wilk, 2023). This approach enables informed decision-making regarding environmental protection and ensures the safety of local communities while minimizing the negative impact on the environment and land use.

5. Conclusions

The asbestos industry has a significant impact on the environment in Cyprus. The land development paradigm has shifted from once densely vegetated mountains to expansive open pit mining operations, progressively altering larger areas within the Troodos Mountains. Concurrently, the region's economic role transitioned from asbestos extraction for profit to changes in land use, including partial conversion for housing the families of mine workers. Presently, the area poses potential risks due to its deteriorated state. Efforts are underway to restore the area to its original state, including reforestation initiatives and the establishment of a Botanical Garden by the Department of Forests. However, an unsecured landfill for hazardous asbestos waste remains nearby. Securing this area and accurately estimating the volume of potential waste, particularly from the dismantling of asbestos-cement roofing nationwide, is crucial. Future research will focus on quantifying the amount of asbestos-containing products using convolutional neural networks. This research provides critical insights into the historical context, environmental impacts, and remediation efforts related to asbestos mining in Cyprus. It highlights the necessity for ongoing monitoring and mitigation strategies and suggests that methods employed in other countries for asbestos-cement product analysis could be effectively adapted for asbestos management in Cyprus.

References

Briassoulis, H. (2020). Analysis of Land Use Change: Theoretical and Modeling Approaches. 2nd ed. Edited by Scott Loveridge and Randall Jackson. WVU Research Repository.

Chollet, F. (2015). Keras. https://keras.io/about/

Constantopoulos, S.H. (2008). Environmental mesothelioma associated with tremolite asbestos: Lessons from the experiences of Turkey, Greece, Corsica, New Caledonia and Cyprus. *Regulatory Toxicology and Pharmacology* 52, 110-15. https://doi.org/10.1016/j.yrtph.2007.11.001

Copernicus Data Space Ecosystem (2024). https://dataspace.copernicus.eu (Accessed on 3 March 2024).
Craighead, J. E. (Ed.), 2008. Asbestos and its diseases. Oxford University Press.

Farazi P.A. (2014). Cancer trends and risk factors in Cyprus. *Ecancermedicalscience*, 8, 389. https://doi.org/10.3332/ecancer.2014.389.

Hendry, N. (1965). The Geology, Occurrences, and Major Uses of Asbestos. Annals of the New York Academy of Sciences 132, 12–21. doi.org/10.1111/j.1749-6632.1965.tb41086.x.

Houk, L.G., Barsigian, F.M. (1949). Asbestos. Minerals yearbook. Year 1947-1949. Washington, D.C. Bureau of Mines, United States Government Printing Office.

Hu, J., Ye, B., Bai, Z. & Feng, Y. (2022). Remote Sensing Monitoring of Vegetation Reclamation in the Antaibao Open-Pit Mine. *Remote Sensing* 14, 5634. https://doi.org/10.3390/rs14225634.

IBAS (2022). International Ban Asbestos Secretariat. http://www.ibasecretariat.org.

International Agency for Research on Cancer, IARC (1977). IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man, Asbestos, Nr 14, World Health Organisation, Lyon.

Kakoulli, I., Prikhodko, S.V., King, A. & Fischer, C. (2014). The earliest evidence for asbestos composites linked to Byzantine wall painting production. *Journal of Archaeological Science* 44, 148-153. doi.org/10.1016/j.jas.2014.01.031.

Keras 3, https://keras.io/api/

Krówczyńska, M., Raczko, E., Staniszewska, N. & Wilk, E. (2020). Asbestos-cement Roofing Identification Using Remote Sensing and Convolutional Neural Networks (CNNs). *Remote Sensing* 12(3), 408. https://doi.org/10.3390/rs12030408

Krówczyńska, M. & Wilk, E. (2023). Hazardous waste in the Anthropocene: The comparative methods for asbestos roofs detection to assess the environmental risk. *The Anthropocene Review* 11(2), 367-383. https://doi.org/10.1177/20530196231207981

Maliotis, G. (2021). The Mines of Cyprus. A Contribution to the Recording and Study of the Cyprus Mining Industry.

MANRE (2022). Biodiversity Conservation in Restoration and Management of the Amiantos Asbestos Mine, in Troodos National Forest Park”. https://www.amiandos.eu/en/ (accessed on 3 October 2022).

Murray, R. (1990). Asbestos: a chronology of its origins and health effects. *British Journal of Industrial Medicine* 47, 361-365. doi.org/10.1136/oem.47.6.361.

Oldfield, F. & Dearing, J.A. (2003). The role of human activities in past environmental change [in:] Paleoclimate, Global Change and the Future, IGBP Synthesis Book Series ed. K. Alverson, R. Bradley and T. Pedersen (Springer)143-62.

Poyiadji, E., Stefouli, M., Przyłucka, M., Wołkowicz, S., Kowalski, Z., Hadjigeorgiou, C., & Woroszkiewicz, M. (2018). Introduction of remote sensing methods for monitoring the under-restoration Amiantos Mine, Cyprus. In: Sixth International Conference on Remote Sensing and Geoinformation of the Environment 10773, 403-412.

Raczko, E., Krówczyńska, M. & Wilk, E. (2022). Asbestos roofing recognition by use of convolutional neural networks and high-resolution aerial imagery. Testing different scenarios. *Building and Environment* 217. https://doi.org/10.1016/j.buildenv.2022.109092.

Report (2005). Report on the Health Effects of the Asbestos Mines on the Population of Neighbouring Communities. Ministry of Health in Cyprus. https://www.moh.gov.cy/ (accessed on 3 October 2022).

Rosato, D.V. (1959). Asbestos. Its industrial applications. Reinhold Publishing Corp. New York.

Sagui, C.L. (1925). Asbestos Deposits of Cyprus. *Economic Geology* 20,371-375.

The Mines Service (2022). Asbestos. http://www.moa.gov.cy/moa/Mines/MinesSrv.nsf/All/19601F76B2F46123C22574EA003392D6?OpenDocument# (accessed on 1 October 2022).

UNESCO Global Geoparks (2022). https://en.unesco.org/global-geoparks (accessed on 3 October 2022).

Virta, R.L. (2002). Asbestos: Geology, Mineralogy, Mining, and Uses. U.S. Department of the Interior U.S. Geological Survey, Open-File Report 02-149. https://doi.org/10.3133/ofr02149.

Virta, R.L. (2006). Worldwide asbestos supply and consumption trends from 1900 through 2003. U.S. Geological Survey Circular 1298. doi.org/10.3133/cir1298.

West, J.M. & Schreck, V.R. (1962). Asbestos. Minerals yearbook: Metals and minerals (except fuels) 1961. Washington, D.C. Bureau of Mines, United States Government Printing Office.

Wilk, E. & Krówczyńska, M. (2021). Malignant mesothelioma and asbestos exposure in Europe. Evidence of spatial clustering. *Geospatial Health* 16(1). https://doi.org/10.4081/gh.2021.951.

Wilk, E., Krówczyńska, M. & Pabjanek, P. (2015). Determinants influencing the amount of asbestos-cement roofing in Poland. *Miscellanea Geographica – Regional Studies on Development* 19(3). https://doi.org/10.1515/mgrsd-2015-0014

Wilk, E., Krówczyńska, M., Pabjanek, P. & Mędrzycki, P. (2017). Estimation of the amount of asbestos-cement roofing in Poland. *Waste Management & Research* 35(5), 491-499. https://doi.org/10.1177/0734242X16683271.

Wilk, E., Krówczyńska, M. & Zagajewski, B. (2019). Modelling the Spatial Distribution of Asbestos-Cement Products in Poland with the Use of the Random Forest Algorithm. *Sustainability* 11(16), 4355. https://doi.org/10.3390/su11164355.

World Health Organisation, WHO (1986). Environmental Health Criteria 53. Asbestos and Other Natural Mineral Fibres. World Health Organization, Geneva.

Xenophontos, C. (1991). Picrolite, Its Nature, Provenance, and Possible Distribution Patterns in the Chalcolithic Period of Cyprus. *Bulletin of the American Schools of Oriental Research* 282/283, 127. doi.org/10.2307/1357266.