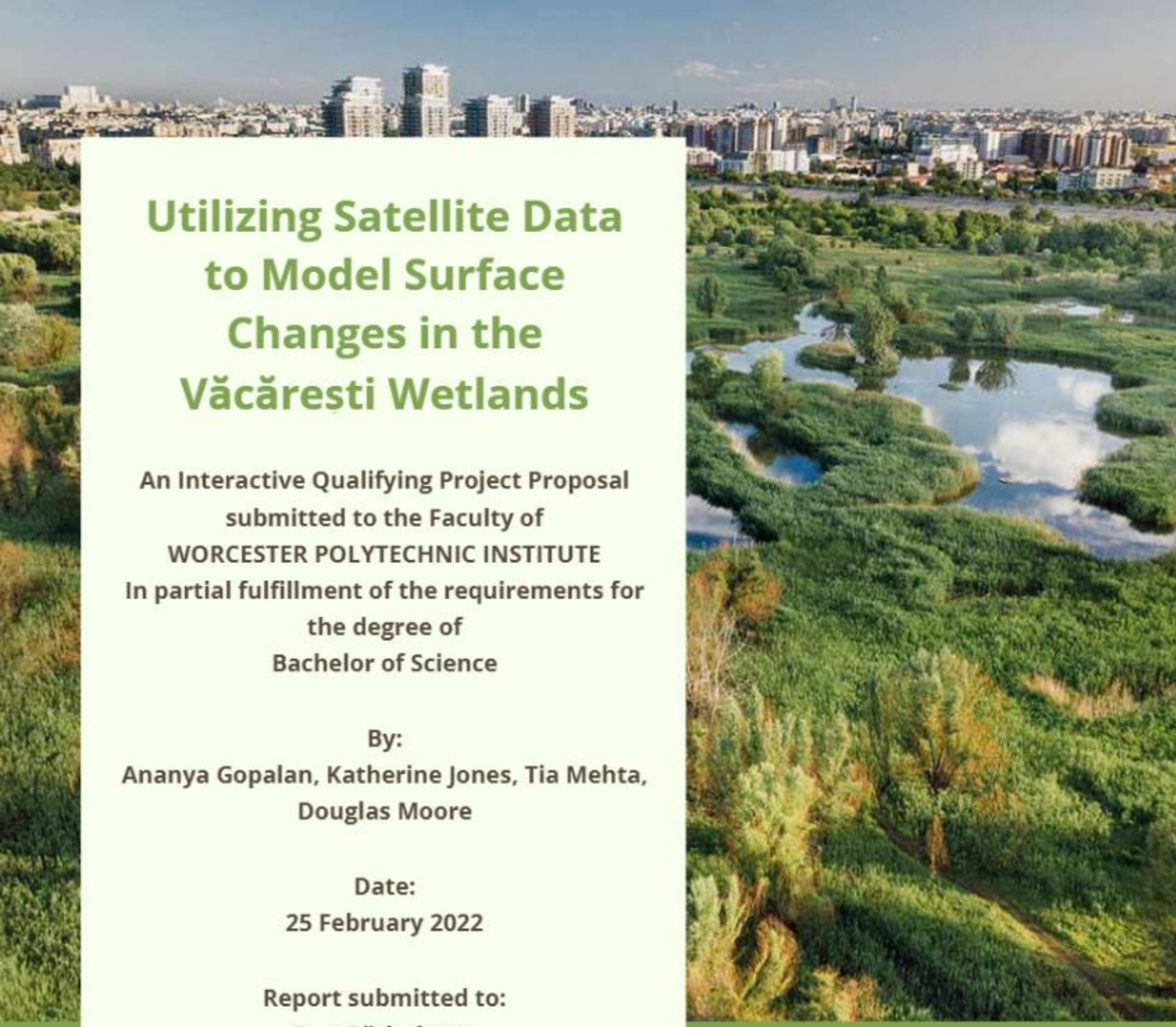

Utilizing Satellite Data to Model Surface Changes in the Văcărești Wetlands

An Interactive Qualifying Project Proposal
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
In partial fulfillment of the requirements for
the degree of
Bachelor of Science

By:
Ananya Gopalan, Katherine Jones, Tia Mehta,
Douglas Moore

Date:
25 February 2022

Report submitted to:
Dan Bărbulescu
Văcărești Nature Park Association

Professors Althea Danielski and Robert Kinicki

PARCUL NATURAL VĂCĂREȘTI

WPI

Utilizing Satellite Data to Model Surface Changes in the Văcărești Wetlands

An Interactive Qualifying Project Proposal
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
degree of Bachelor of Science

by
Ananya Gopalan
Katherine Jones
Tia Mehta
Douglas Moore

Date:
6 March 2022

Report Submitted to:

Dan Bărbulescu
Văcărești Nature Park Association

Professors Althea Danielski and Robert Kinicki
Worcester Polytechnic Institute

Table of Authorship

Section	Lead Author
1.0 Introduction	All
2.0 Background	Ananya
2.1 Origins of the Wetlands	Tia, Ananya
2.1.1 Management of Natural Protected Areas	Tia
2.1.2 Public Perception of NGOs	Ananya
2.2 Park Degradation: Climate Change and Drought	Kate
2.2.1 Wetland Conservation	Kate
2.3 Potential Value of the Wetlands	Douglas
2.3.1 Economic Incentives	Douglas
2.3.2 Community Benefits	Douglas
2.3.3 Environmental Services of Accidental Ecosystems	Kate
2.4 Geographic Information Systems	Douglas
2.4.1 Previous uses of GIS to Model Water Surface Changes over Time	Douglas
2.4.2 Copernicus Satellite Data	Douglas
2.4.3 QGIS and Normalized Difference Water Index	Douglas
3.0 Methodology	All
3.1 Interviews	Tia
3.1.1 Interviewing VNPA Leadership	All
3.2 Copernicus, GIS, and NDWI Methods	Douglas
3.3 Conclusion	All

All authors contributed to edits and revisions of each section.

Table of Contents

Table of Figures

1.0 Introduction

Wetlands ecosystems are particularly susceptible to the impacts of climate change and drought. For decades, southeastern Romania has experienced an increasingly arid climate (Dobri et al., 2021). Even during the "wettest years," (2010, 2014, 16, and 2018) drought affected this region of Romania (Dobri et al., 2021). The steady rise of global temperatures has accelerated the rate of evapotranspiration (the process by which moisture from the soil and other surfaces is absorbed by the atmosphere). The atmosphere absorbs once-plentiful groundwater, leaving wetland water sources scant (Dobri et al., 2021). These ecosystems are extremely sensitive, and the impacts of climate change could cause altered hydroperiods (the period of the year during which wetlands hold water), more frequent extreme weather events, and increased heat stress on resident plant and animal species. Water surface area is an important part of the water cycle and is critical for biodiversity and environmental stability in wetlands (Hussaini et al., 2019). Climate change has affected the Văcărești Wetlands in Bucharest, Romania, causing its water surface area to steadily dwindle over the years, with groundwater depleting due to drought and overgrown reed beds (Bărbulescu, 2022). The Văcărești Nature Park Association (VNPA) is the organization that maintains these wetlands.

The Văcărești Wetlands is an important greenspace in the heart of Bucharest, Romania, that serves as an ecotourism destination and a home for many protected species. Environmentalists established the VNPA, a Romanian NGO, with the purpose of protecting the park ecosystem and wildlife (*Our Association – Parcul Natural Vacaresti*). However, the VNPA is struggling to maintain the wetlands due to the lack of government aid. In recent years, the government has shifted focus to funding social issues that arose during Romania's transition

from a communist to democratic regime. The environmentalists of the VNPA saw a need to take action because the government was not focused on funding environmental causes. An absence of financial support specifically limits the VNPA's ability to monitor and address decreasing water levels adequately.

The lack of maintenance has led to a noticeable decrease in the water surface area of the Wetlands. The team will use geographic information system (GIS) software and satellite images to analyze current and historic water surface area in the Wetlands. Previous research teams have conducted surface area analysis on other large bodies of water using satellite imagery and GIS software, but researchers have never studied the Vacaresti Wetlands in this manner (Ali & Jaber, 2020; Hussaini et al., 2019). The team will conduct research on a smaller geographical scale and with more frequent imaging than in past studies, and use the findings to create a presentation for the VNPA that illustrates the severity of the problem and the consequences that will occur if the government does not take action.

The goal of this project is to assist the Văcărești Nature Park Association in showing policy makers the importance of increasing water surface area. The team will accomplish this by completing the following objectives:

1. Understand how declining water surface area will affect plant and animal ecosystems in the park.
2. Create GIS models of the Văcărești Wetlands to show how water surface area will change in the future.
3. Present findings to the VNPA for their use in attracting government attention.

2.0 Background

This chapter introduces the challenges the Văcărești Nature Park Association (VNPA) face as they work to maintain the wetlands with little support from the Romanian Government. The chapter begins with a brief discussion of Romanian history and how it affects the social, political, and economic culture today. The following section describes the potential economic and environmental values of the Wetlands. The last section details the recent deterioration of the Wetlands due to drought and climate change and its implications on the health of the park's ecosystem.

2.1 Origins of the Wetlands

The Văcărești Wetlands is the largest "compact green space" in Bucharest and covers an area of 183 hectares (*Văcărești Nature Park – Parcul Natural Vacaresti*, n.d.). In addition to biodiverse species and habitats, the VNP also offers an interesting contrast between the urban, anthropized area and the natural wetland with expanses of reed, swamps and wetland-specific trees and vegetation. While visiting Văcărești in 2012, Tobias Salathe, a senior advisor for Europe at the RAMSAR Convention on Wetlands of International Importance, stated: "Văcărești will undoubtedly be one of the most innovative urban wetland projects in the world" (*Brief History – Parcul Natural Vacaresti*).

The land the park sits on was not originally intended to be a diverse wetland reserve. During the late 1970s and early 1980s, Romania's communist leader Nicolae Ceaușescu forcefully industrialized Romania without considering the impact of his actions on other areas of development within the country. This rapid industrialization led to a lack of focus in areas

such as urban planning and environmental governance. In 1988, the communist regime began extensive hydrotechnical development on the Văcăreşti Lake.

Figure 2.1. A photo of the Văcăreşti Reservoir in 1989 (Andrei Birsan Vacaresti 1989_web.Jpg (1908×1242), n.d.)

The government intended for the site to be a part of the flood-defense hydraulic-engineering system in Bucharest. To make room for the Văcăreşti Lake reservoir (Figure 2.1 shows this is 1989), the regime destroyed the Văcăreşti borough (a neighborhood of individual dwellings). Designers abandoned the project after the fall of communism in 1989 and its status remained uncertain until 2002, when the land was auctioned off to private investors (Ianos et al., 2014). Figure 2.2 shows an aerial view of the park taken around 2015.

Figure 2.2. Aerial view of the Văcărești Nature Park in 2015 (How Nature Turned a Failed Communist Plan into Bucharest's Unique Urban Park | Cities | The Guardian, n.d.)

2.1.1 Government Funding for NGOs

Following the collapse of communism in 1989, Romania began the shift from a socialist to democratic government. The country faced difficulty restructuring an outdated industrial base, rebuilding an agricultural sector that was inefficient, and removing government subsidies for consumer goods. This period of regrowth engendered the rise of many non-governmental organizations (NGOs). While the government made much progress towards a functional democratic society in the late 90s to early 2000s, the 2008 global economic crash slowed the pace of liberalization and privatization of services needed for a well-functioning market economy (Constantin et al., n.d.). This resulted in high levels of poverty, unemployment, skyrocketing inflation, and shortages of consumer goods. These became the primary focus of government aid, rather than NGOs.

The government is reluctant to fund NGOs unless they are sure of a return on investment. Therefore, NGOs are unable to complete much work on their own (Zbuchea & Bîr, n.d.). The public perception of the usefulness of NGOs is low. This is because of the divide between the public and policy makers (Zbuchea & Bîr, n.d.). The local government focuses on issues policymakers consider important, such as official events and legislative initiatives, overshadowing the wants of the people. This lack of funding hinders the VNPA's efforts to maintain the park.

2.1.2 Management of Natural Protected Areas

The Văcărești land began to garner attention in 2012 after the publication of the article "The Delta Among the Blocks" in the May issue of the National Geographic magazine. The article pointed out the rich biodiversity of the area, and introduced the idea of turning the land into a nature park. Dan Bărbulescu, along with a group of environmental protection activists and experts, started the VNPA and began to lobby for the protection of the Văcărești area. The group received project support from Kogayon, National Geographic România, Salvați Dunărea și Delta (Save the Danube and the Delta) Association and Ecopolis. Government decision no. 349/2016 established the VNP in 2016, and it became the first urban nature park in Romania (Our Association – Parcul Natural Vacaresti).

In 2018, the Romanian government passed an emergency ordinance banning environmental NGOs from managing nature protected areas and delegated the control to the National Agency for Protected Natural Areas (ANANP), a subset of the Ministry of Environment (*Protected Areas in Romania without Custodians and Protection?*, n.d.). The ANANP has since failed to provide the solutions and resources needed for the VNP to reach the

stage of maintenance it was at previously. The park no longer has a functional management structure, a scientific and advisory council, nor a ranger force. The VNPA wrote a letter to the ANANP in 2020 requesting a park guard, regulation, and a formal management plan for the purpose of biodiversity conservation and ecological reconstruction (*Organizațiile Non-Guvernamentale Din România Cer Protecție Pentru Parcul Natural Văcărești*). The ANANP denied all their requests, leaving the VNPA unable to manage the park properly, contributing to the decline of the Wetlands.

2.2 Park Degradation and the Need for Conservation

Drought and climate change, both largely unavoidable, currently threaten the health and longevity of the Văcărești Wetlands. There are many factors that contribute to the onset of drought, such as precipitation amounts, soil character, humidity, and wind speed (Dobri et al., 2021). Between the years 2001 and 2020, southeastern Romania experienced a decrease in precipitation combined with an increase in evapotranspiration (Dobri et al., 2021). Evapotranspiration is the simultaneous process of soil moisture evaporation and plant transpiration. This combination contributes greatly to an uptick in the aridity of the region, amplifying the effects of the drought.

The pressures on wetlands due to climate change are likely to come in the form of changes in hydroperiod (the portion of the year during which wetlands hold water), extreme weather events, and deviations from average temperature. These climate events can lead to altered groundwater flow and depth, invasive species rampaging habitats, and increased heat stress on wildlife (Erwin, 2009). Because wetlands are extremely sensitive to changes in the quality and quantity of their water supply, both climate change and drought are greatly

detrimental to the health of these ecosystems. A reduction in the water surface area of the park means loss of potential habitat space for aquatic species, as well as limiting the growth of vegetation that uses this water supply. Shrinking populations of these species leads to a disrupted food chain in the ecosystem.

An important strategy for the management of wetlands is the reduction of stressors that inhibit the ecosystem's ability to respond to climate change. In the case of the Văcăreşti Wetlands, an example of these stressors is the spread of overgrown invasive reed beds. Reeds and other grasses use a higher amount of water than other vegetation, drawing too heavily upon the already dwindling water supply. The reeds can also grow to such heights that they block visibility of other areas of the park. Figure 2.3 shows a group of tourists on a trail in the park, surrounded by tall reeds.

Figure 2.3 Reeds beds in the Vacaresti Nature Park (3-1.Jpg (1250×834), n.d.)

2.3 Potential Value of the Wetlands

The conservation of the nature park is mutually beneficial to the environment and the municipality. City planners and policy makers have the opportunity to take advantage of the aforementioned ecosystem services that the wetlands provide. Municipalities can design selective management strategies to increase the output of desired services, such as the mitigation of pollution and heat.

The government and NGOs can reach a mutual benefit (Cheng, 2019). For example, funding for parks contributes to the upkeep of park activities and vegetation, inherently increasing ecotourism, which is financially beneficial to the government. A nonprofit such as the VNPA can organize events that bring locals together and raise the public's perceptions of NGOs. In this way, funding nonprofits is not only beneficial to the government and the nonprofit, but also the community as a whole.

2.3.1 Economic Value

Over time, the government can recoup initial costs of funding an NGO and create sustainable economic growth for a region. The Central Park Conservancy (CPC) in New York is a nonprofit organization that was founded in 1980 in order to restore the park from previous decades of neglect. It employs over 300 staff members and has around 3400 volunteers as of 2021. (In comparison, the VNPA has about 15 active volunteers). As a result of the CPC's restoration efforts, the park now brings an estimated $1.4 billion in revenue to New York City (Castle, 2021). Although the CPC is not funded by the US government, it is a good example of how investing in ecotourism destinations can positively benefit a region's economy. Globally, 40-60% of all tourists are nature tourists, and ecotourism accounted for around 20% of global

travel in 1998 (The International Ecotourism Society, 2000). Similar to Central Park, the Văcărești Wetlands has the potential to bring about sustainable economic growth to Bucharest if it is properly maintained. In 2020, foreign tourists spent a total of 1.18 billion Romanian Leu (270 million USD) (Chirileasa, 2021).

2.3.2 Community Benefits

Along with its potential economic impact, the Văcărești Wetlands also provides valuable community space. There are trails for joggers, walkers, and cyclists in the park (Figure 2.4), as well as bird watching areas with observation towers (Figure 2.5). Within large cities like Bucharest, access to protected nature areas is especially beneficial. Urban green spaces have been linked to "physical and psychological benefits" (Lee & Maheswaran, 2011). Possible benefits include increased cardiovascular health, bone health, and mental well-being (Lee & Maheswaran, 2011).

Figure 2.4 A group of cyclists using a trail in the Văcărești Nature Park (WALKING DOWN AND BY BIKE - Vacaresti Natural Park, n.d.)

Figure 2.5 People using an observation deck in the park (WALKING DOWN AND BY BIKE - Vacaresti Natural Park, n.d.)

The park's educational value is also important. Park leadership conducts field trips with local schools and provides guided nature walks, educating the public about biodiversity and the importance of urban greenspaces. Figure 2.6 shows a park ranger giving a tour to students. Raising awareness of environmental issues is important, especially as drought and desertification have swept over many parts of Romania and Eastern Europe in recent years (Welle (www.dw.com), n.d.).

Figure 2.6. A park ranger talking to a group of local students (BSB Science, 2018)

2.3.3 Environmental Services of Accidental Ecosystems

Accidental urban wetlands form as a byproduct of municipal infrastructure and can have organismal, hydrological, and soil systems similar to those in natural wetlands (Palta et al., 2017). Ecosystem services are "a means of assessing, managing, or designing" (Palta et al., 2017) environments to maximize the benefits ecosystems can provide. These systems are

smaller subdivisions of larger accidental ecosystems and can provide the same functions and services as their organic counterparts (Palta et al., 2017). Examples of such services include mitigation of heat and pollution, along with carbon sequestration (the process of capturing and storing carbon dioxide from the atmosphere). These accidental environments can serve as low-cost means of reducing urban pollution, as well as providing habitats for vulnerable species.

The Văcăreşti Wetlands are home to an incredibly biodiverse array of flora and fauna. The current floristic inventory of the park lists 101 taxa, including *Wolffia arrhiza*, a rare species of flowering plant threatened at a national level. The wetlands are also home to over 138 bird species, 6 orders of insects, and a variety of amphibians and mammals, such as otters, as seen in Figure 2.7, and foxes. (*Biodiversity – Parcul Natural Vacaresti*, n.d.)

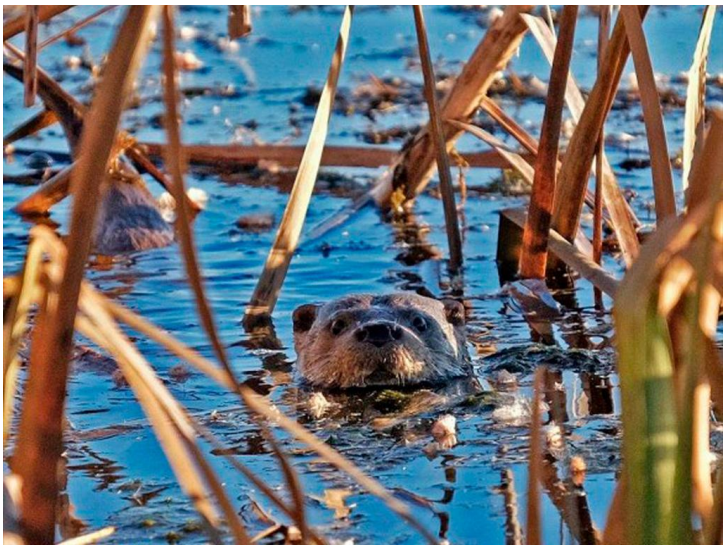

Figure 2.7. Image of an otter swimming in the Wetlands (Biodiversity – Parcul Natural Vacaresti, n.d.)

2.4 Geographic Information Systems

Geographic Information Systems (GIS) are computer programs that can be used to analyze data in fields such as earth sciences, biology, resource management, hydrology, and

many other fields, using geological data. The team plans to use satellite images and GIS software to model the hydrology of Văcărești Nature Park. The models will show clear evidence of decreasing water surface area in the Wetlands, which the VNPA can use to bolster their need for government funding.

2.4.1 Previous uses of GIS to Model Water Surface Changes over Time

GIS software has been used to model water surface area changes in wetlands and lakes. By looking at previous studies, the team was able to compare methods utilized by previous researchers. In Central Africa, for example, the Lake Chad Basin's surface water area shrank by more than 90 percent over the span of five decades as a result of climate change and drought (Hussaini et al., 2019). A team from the geography department at Aminu Saleh College in Nigeria used GIS software and satellite images to map surface water area over time, highlighting the changes from 1985 to 2015. The team focused on surface water area, as it is an important part of the water cycle and is critical to environmental sustainability (Hussaini et al., 2019). Figure 2.8 shows images the team produced to highlight shrinking surface water area. The dark blue areas are surface water, green areas are different types of foliage, and tan and light blue are areas of farmland and barren land.

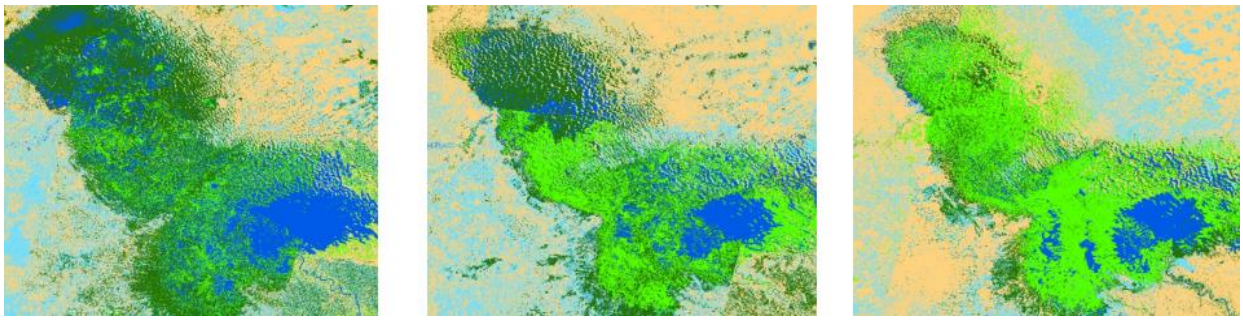

Figure 2.8. Processed images detailing shrinking water surface area in Lake Chad (Hussaini et al., 2019)

Another study in 2020 examined water levels in Razzaza Lake in Iraq using satellite images from 1998, 2008, and 2018. Wetland areas used to surround Razzaza Lake, providing habitats for birds, fish, and reptiles, but shrinking water surface area reduced the number of resources available to these animal populations, negatively impacting biodiversity (Ali & Jaber, 2020). The team used satellite imagery to create maps of areas with deep water, arable land, and barren soil. Figure 2.9 shows the shrinking regions of deep water in the lake. The lake lost 57.9% of its deep water areas and 38.7% of its shallow water areas since 1998 (Ali & Jaber, 2020). The team determined from these case studies the benefits of using GIS software. This is an efficient tool that will allow the team to process and simplify satellite data.

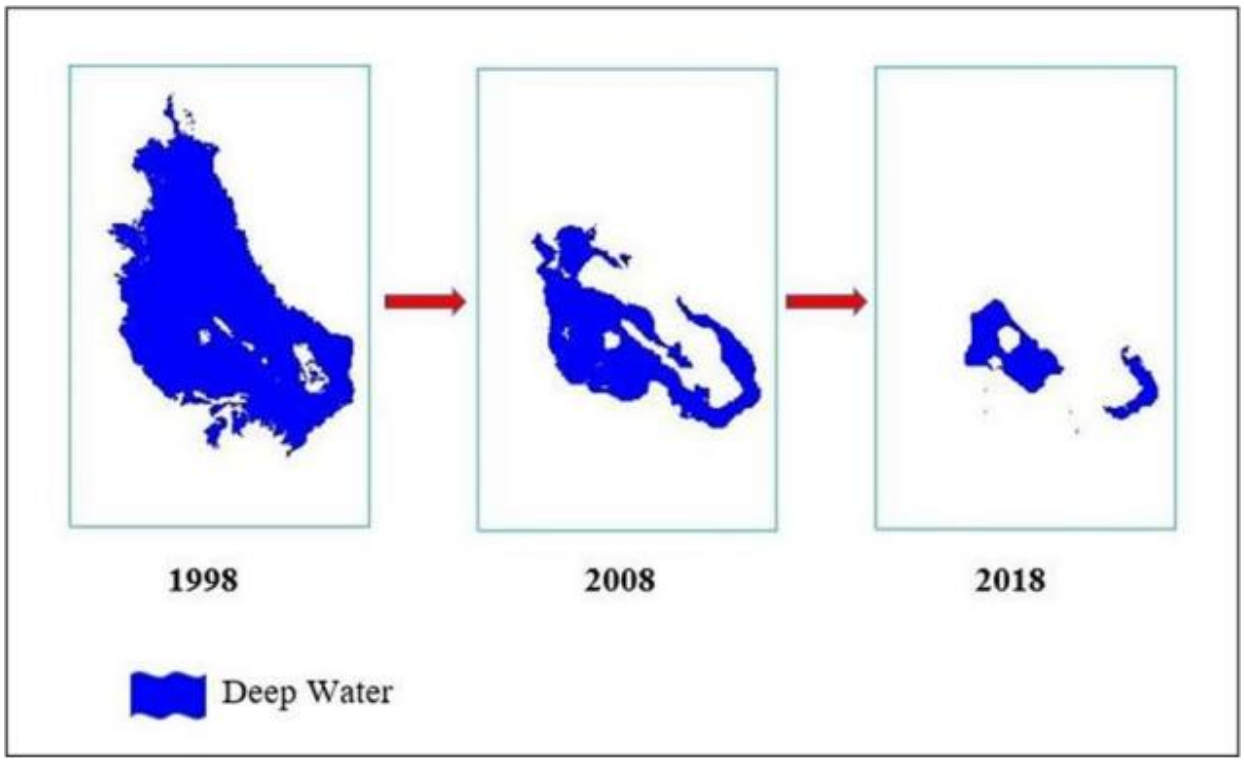

Figure 2.9. Deep water areas in Razzaza Lake over time (Ali & Jaber, 2020)

2.4.2 Copernicus Satellite Data

The Copernicus program is the European Union's earth observation program made in partnership with the European Space Agency. Copernicus satellite images are available to the public at no charge, and their records go back to the start of the program in 2014 (*Copernicus in Detail | Copernicus*, n.d.). The cameras on the satellites in the Copernicus program can distinguish features down to 10 meters in size, and the satellites revisit the same area every 5 days to take new photos (*Sentinel-2 - Missions - Resolution and Swath - Sentinel Handbook - Sentinel Online*, n.d.) The satellites take images in the visible spectrum and with infrared and thermal cameras. The team will use visible and infrared images in order to create maps of surface water in the park, and use those images to determine trends of surface water over time.

2.4.3 QGIS and Normalized Difference Water Index

The team plans to use QGIS, a free and open source GIS program, in order to determine surface water area in satellite images using Normalized Difference Water Index techniques. The Normalized Difference Water Index (NDWI) is a number that measures the ratio of green to near-infrared light that an object reflects. Water reflects green light but absorbs near-infrared light very well. GIS software uses NDWI to extract surface water features from satellite images using the equation in Figure 2.10.

$$NDWI = \frac{Green\ Channel\ Brightness - Near\ Infrared\ Brightness}{Green\ Channel\ Brightness + Near\ Infrared\ Brightness}$$

Figure 2.10. NDWI formula

Figure 2.11 shows an example of an image generated with NDWI methods. On the left is an unprocessed satellite image, and on the right is an image after processing in GIS software using NDWI. Areas that are water are highlighted in white, while land is shown in black.

Figure 2.11. Water body extraction from satellite images (Geo Guru, 2020)

NDWI values above zero indicate bodies of water, and values below zero are land. Figure 2.12 shows an image the team generated in the GIS software using Copernicus satellite data of the Văcărești Wetlands from 2021. Black pixels are water features, white are non-water features, and the red areas are boundaries of the park. NDWI analysis offers a way to quickly and accurately determine the amount of surface water in an image, which will be useful to our project.

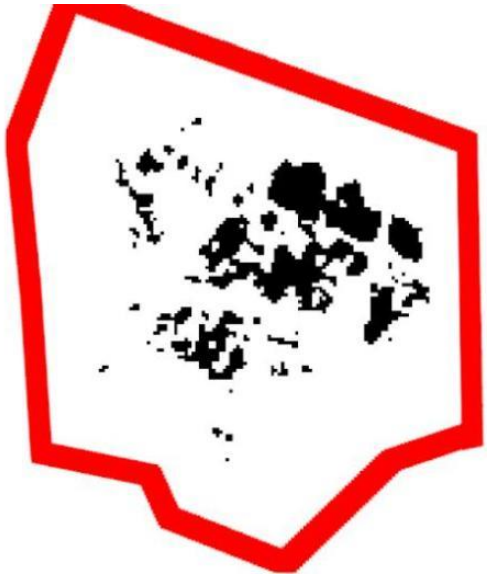

Figure 2.12. VNP Water body extraction in GIS software using NDWI

3.0 Methodology

The goal of this project is to assist the Văcărești Nature Park Association in showing policy makers the importance of increasing water surface area. The team will accomplish this by completing the following objectives:

1. Understand how declining water surface area will affect plant and animal ecosystems in the park.
2. Create GIS models of the Văcărești Wetlands to show how water surface area will change in the future.
3. Present findings to the VNPA for their use in attracting government attention.

The team will spend the first two weeks of the term (March 14th through March 23rd) in Worcester learning how to conduct surface water feature extraction in GIS software. The team's technical lead has researched GIS systems by watching YouTube tutorials and reading supporting documentation. This team member will train the rest of the group during the remote period of the IQP term. The team will simultaneously be conducting semi-structured interviews over Zoom with the VNPA management. The goal of these interviews is to better understand current park management and changes in the park ecosystem. This task will prepare the team with the necessary skills and information needed to carry out the objectives of the project. The team intends to complete the remaining interviews and modeling on site in Bucharest during the IQP term from March 25th to May 3rd. Using QGIS, the team will process images captured by the Copernicus program's satellites which began taking photos in 2014. The team will use this data to graph changes in the water surface area using a time series analysis. The team will implement linear regression techniques to create a predictive model of future water surface area.

In order to understand the effects of declining water levels on the park, the team will continue interviews with the VNPA staff. Using findings from the models and interviews, the project members will create a presentation and technical document for the VNPA. Both will illustrate the effects of declining water levels on the park ecosystem. The team will design a presentation for the general public, using more accessible language, while the technical document will be more detailed and comprehensive. The VNPA can then use this information as they see most appropriate to attract government attention towards the Wetlands.

3.1 Interviews

The team will conduct interviews with VNPA staff, including ecology specialists, landscape engineers, and park leadership. The team will read to the interviewees the informed consent guidelines detailed in Appendix A. The project interviews will be semi-structured with an anticipated length of 30-45 minutes and at least two team members will be present to conduct the interviews. The team plans to record the interviews with the permission of the interviewees, requested before the interview takes place and to transcribe the recording afterward. If the interviewee does not consent to recording, one member of the team will transcribe as the other conducts the interview. For interviews where English is not the interviewee's primary language, the team's interviewer will be prepared to reword questions to avoid misunderstandings. If the interviewee is not comfortable speaking English, the team will contact WPI's Department of Integrative and Global Studies to recruit a translator.

These interviews will provide the team with more information about the VNPA's financial resources, park maintenance, government relations, and wetland ecology. Once in Bucharest, the team will conduct in person interviews with the rest of the VNPA staff.

3.1.1 Interviewing VNPA Leadership

The VNPA comprises twelve employees including the four founding members. Of these members, the team will first interview Dan Bărbulescu, the founding member and executive director of the VNPA to gain knowledge on holistic park management. The team will then prioritize the following members:

Name	VNPA Position
Vlad Cioflec	Biologist
Bogdan Mihalache	Landscape Engineer
Florin Stoican	President
Nicoleta Marin	Park Ranger

The interview will begin with question A.1 (see Appendix A), which pertains to the interviewee's history with the VNPA. Questions A.2-A.4 will establish the financial and physical resources the VNPA currently has, and questions A.5 and A.6 refer to park maintenance. Questions A.7-A.10 are about the VNPA's relationship with the government. Questions A.11-A.16 ask about wetland ecology. The results of these interviews will strengthen the team's understanding of the connection between the park's funding, maintenance, and ecosystem. These interviews along with literary research are the primary steps the team will take towards completing Objective 1.

3.2 Copernicus, GIS, and NDWI Methods

The technical component of this project involves processing and analyzing satellite images from the Copernicus program in GIS software, using NDWI techniques and time series analysis. The team will use these trends to understand the future trajectory of water surface area through linear regression analysis. Figure 3.2 maps out the flow of technical work in the project.

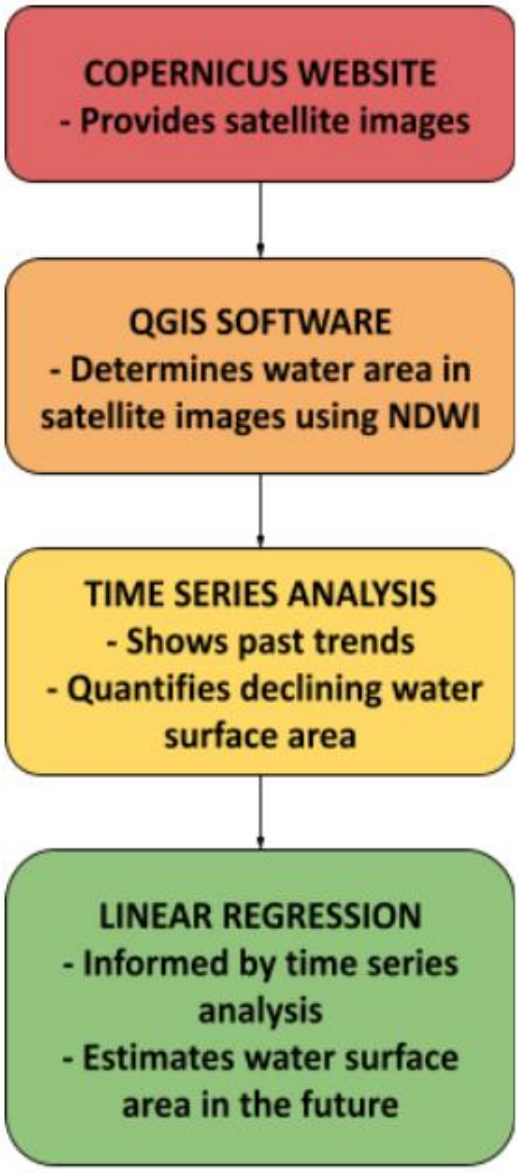

Figure 3.1. Flowchart for technical work in the project

The team will examine satellite images from 2014 to present day, sourcing data from the Copernicus program website. The team will download an image from each month of the year and import the data into QGIS software. NDWI techniques in QGIS will determine the amount of water surface area in each image in hectares, and then the team will plot the amount of water surface area over time using time series analysis.

Once the time series plot is complete, the team will perform linear regression analysis in Excel to estimate water surface area in the park over the next 5-10 years. The predictions from the linear regression should provide objective evidence that the park will continue to deteriorate without assistance in the form of government funding.

3.3 Conclusion

This section describes the culmination of the project and how the team will create the final deliverable. By the end of the project term, the team will finalize results of the project and present them to the VNPA. The interviews conducted to complete Objective 1 will provide the information that motivates this project. The importance of understanding how changing water surface area will negatively affect plant and animal ecosystems in Objective 1 serves as the motivation behind the project. Creating GIS models of the Wetlands in Objective 2 will provide concrete evidence of the reduced water surface area and predict future trends in the park. The work done to complete both these objectives will provide the information needed to create the deliverable in Objective 3, a comprehensive technical document and presentation that the team will give to the VNPA. This will show how the park ecosystem will be harmed if past trends are allowed to continue.

The ultimate goal is to provide the VNPA with resources that will help them convince the Ministry of Environment to provide financial and managerial assistance to increase the water surface area of the Wetlands.

References

Ali, & Jaber. (2020). Monitoring degradation of wetland areas using satellite imagery and geographic information system techniques. Iraqi Journal of Agricultural Services, *51*(5), 1474–5148. https://doi.org/10.36103/ijas.v51i5.1158

Andrei_Birsan_Vacaresti_1989_web.jpg (1908×1242). (n.d.). Retrieved March 1, 2022, from https://parcnaturalvacaresti.ro/wp-content/uploads/2020/12/Andrei_Birsan_Vacaresti_1989_web.jpg

Biodiversity – Parcul Natural Vacaresti. (n.d.). Retrieved February 1, 2022, from https://parcnaturalvacaresti.ro/en/biodiversity/

Cheng, Y. (Daniel). (2019). Nonprofit spending and government provision of public services: testing theories of government–nonprofit relationships. *Journal of Public Administration Research and Theory*, *29*(2), 238–254. https://doi.org/10.1093/jopart/muy054

Constantin, D. L., Goschin, Z., & Danciu, A. R. (n.d.). The Romanian Economy from Transition to Crisis. 17.

Copernicus in detail | Copernicus. (n.d.). Retrieved February 22, 2022, from https://www.copernicus.eu/en/about-copernicus/copernicus-detail

Cuganesan, S., & Floris, M. (2020). Investigating perspective taking when infrastructure megaproject teams engage local communities: Navigating tensions and balancing perspectives. *International Journal of Project Management*, *38*(3), 153–164. https://doi.org/10.1016/j.ijproman.2020.01.006

DESPRE PARC – Parcul Natural Vacaresti. (n.d.). Retrieved February 22, 2022, from https://parcnaturalvacaresti.ro/parcul/

Dobri, R.-V., Sfîcă, L., Amihăesei, V.-A., Apostol, L., & Ţîmpu, S. (2021). Drought extent and severity on arable lands in Romania derived from normalized difference drought index (2001–2020). *Remote Sensing*, *13*(8), 1478. https://doi.org/10.3390/rs13081478

Erwin, K. L. (2009). Wetlands and global climate change: The role of wetland restoration in a changing world. *Wetlands Ecology and Management*, *17*(1), 71–84. https://doi.org/10.1007/s11273-008-9119-1

Geo Guru. (2020, April 13). *Water body extraction (NDWI) in QGIS*. https://www.youtube.com/watch?v=y_Ah7Zv-o0k

Hitchins, K. (2013). *A Concise History of Romania*. Cambridge University Press, Cambridge, England. https://doi.org/10.1017/CBO9781139033954

How nature turned a failed communist plan into Bucharest's unique urban park | Cities | The Guardian. (n.d.). Retrieved February 4, 2022, from https://www.theguardian.com/cities/2016/jun/14/nature-europe-urban-protected-area-vacaresti-nature-park-romania

Hussaini, A., Mahmud, M. R., Tang, K. K. W., & Abubakar, A. G. (2019). Water level fluctuation assessment of Lake Chad for environmental sustainability using remote sensing and geographic information system technique *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-4/W16*, 261–266. https://doi.org/10.5194/isprs-archives-XLII-4-W16-261-2019

Ianos, I., Florentina-Cristina, M., George, M., Zamfir, D., Stoica, I., & Vlăsceanu, G. (2014). Unclear perspectives for a specific intra-urban space: Văcăreşti lake area (Bucharest City). *Carpathian Journal of Earth and Environmental Sciences*, *9*, 215–224.

Ianoş, I., Sorensen, A., & Merciu, C. (2017). Incoherence of urban planning policy in Bucharest: Its potential for land use conflict. *Land Use Policy*, *60*, 101–112. https://doi.org/10.1016/j.landusepol.2016.10.030

Organizațiile non-guvernamentale din România cer protecție pentru Parcul Natural Văcărești. (n.d.). Retrieved February 22, 2022, from https://parcnaturalvacaresti.ro/2020-09-01-organizatiile-non-guvernamentale-din-romania-cer-protectie-pentru-parcul-natural-vacaresti/

Our Association – Parcul Natural Vacaresti. (n.d.). Retrieved February 22, 2022, from https://parcnaturalvacaresti.ro/en/our-association/

Palta, M. M., Grimm, N. B., & Groffman, P. M. (2017). "Accidental" urban wetlands: Ecosystem functions in unexpected places. *Frontiers in Ecology and the Environment*, *15*(5), 248–256. https://doi.org/10.1002/fee.1494

Protected areas in Romania without custodians and protection? (n.d.). Retrieved January 22, 2022, from https://wwf.panda.org/wwf_news/?332550/Protected-areas-in-Romania-without-custodians-and-protection

Sentinel-2—Missions—Resolution and Swath—Sentinel Handbook—Sentinel Online. (n.d.). Retrieved February 22, 2022, from https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/instrument-payload/resolution-and-swath

SPECIES AND HABITAT - Vacaresti Natural Park. (n.d.). Retrieved February 22, 2022, from https://parcnaturalvacaresti.ro/biodiversitate/

Zaharia, V., & Găitănaru, D. (2018). Aspects of water budget in Văcăreşti Wetland. *Mathematical Modeling in Civil Engineering*, *14*(1), 12–23. https://doi.org/10.2478/mmce-2018-0002

Zbuchea, A., & Bîr, M. (n.d.). The Romanian cultural NGOs and the online citizen: A rendezvous manque? 31.

Appendices

Appendix A: VNPA Staff Interview Questions

Informed Consent

We are students from Worcester Polytechnic Institute, Massachusetts, United States, and we are here to talk more in depth about the Văcărești Nature Park Association's (VNPA) current process of park management, financial resources, government relationship, and wetland ecology. This interview will take approximately 45-60 minutes. Your participation is completely voluntary, and you may stop the interview at any time or refuse to answer any question that we ask. Your name will remain confidential unless you agree to have your name published. We will publish the results, though the respondent has the right to retract any statements said during the interview before May 1st, 2022. We can be reached at gr-wetlands-d22@wpi.edu. For more information about this research or about the rights of research participants, in case of research-related injury, contact the WPI IRB Manager Ruth McKeogh at (508) 831-6699 or irb@wpi.edu and the Human Protection Administrator Gabriel Johnson at (508) 831-4989 or gjohnson@wpi.edu.

By signing your name below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

_____	_____
Interviewee Signature	Date
_____	_____
Signature of person who explained this study	Date
_____	_____
Sign here if you consent to having your name published	Date

Interviewee Background

A.1. Describe your role at the VNPA.

a. How long have you worked at the VNPA?

b. Why did you first get involved with the organization?

c. What kind of work do you specialize in?

VNPA Resources

A.2. Describe the financial resources of the VNPA

a. Where does the VNPA get its budget from (i.e. government, other organizations, donations, etc.)?

b. How has financial resources impacted VNPA projects?

A.3. Describe the physical resources of the VNPA (i.e., people, equipment, etc.)?

a. How has physical resources impacted VNPA projects?

A.4. What connections does the VNPA have with other organizations?

VNPA Park Maintenance

A.5. What maintenance is regularly performed at the park?

A.6. Are there any areas of park maintenance that are currently lacking? If so, explain.

a. What kinds of maintenance does the government allow?

b. What kinds of maintenance is prohibited?

VNPA and Government Relations

A.7. Are you familiar with the relationship between the National Agency for Protected Natural Areas and the VNPA?

a. What assistance do you receive from the National Agency for Protected Natural Areas?

b. We have heard that the Romanian government has prohibited NGOs from managing protected nature areas since 2018. Has this affected the way you work in the park?

A.8. If you were given governmental funding, what would you do with it and where would the money go (in regards to the Văcărești Wetlands)?

A.9. What would you like to see for the future of the Vacaresti Wetlands?

A.10. What would you like to see for the future of the VNPA?

Wetlands Ecology

A.11. Since beginning work here, have you observed any changes to vegetation in the park?

A.12. Have you observed any changes in wildlife in the park?

A.13. Have you observed any changes to the bodies of water in the park?

A.14. Do you have any concerns about the sustainability of the park's ecosystem?

A.15. What do you think is likely to happen if water levels continue to drop?

A.16. How might predictions about water levels help VNPA protect the park?