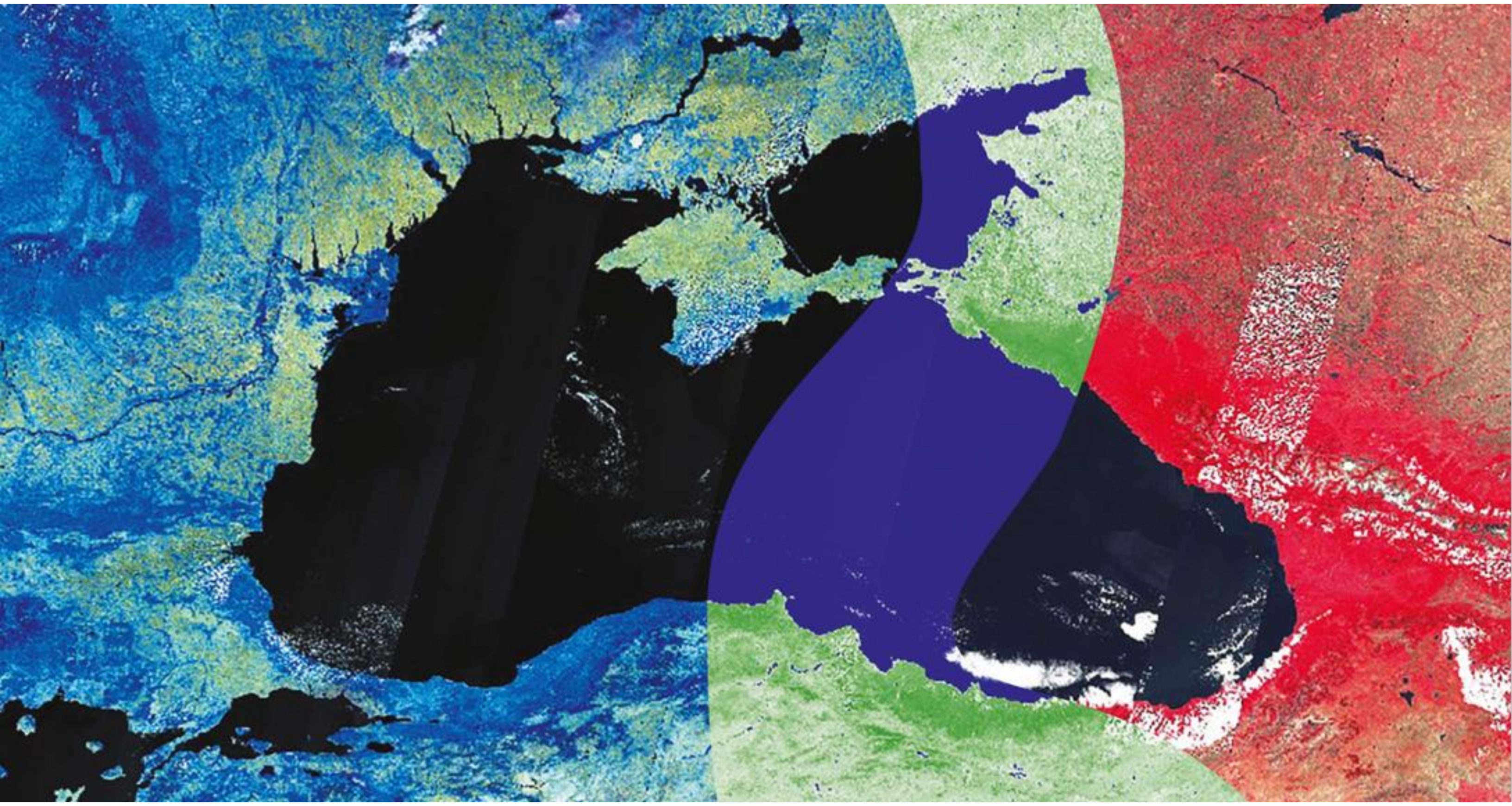
Project funded by EUROPEAN UNION

Copernicus assisted environmental monitoring across the Black Sea Basin – PONTOS



Assessment on forest cover changes and its consequences for the environment

Deliverable D.T1.2.2

PONTOS-AM (Armenia)

Sevan Lake and its catchment area

Table of Contents

Executive summary 4
1.1 Introduction and Background 4
1.2 Purpose of the assessment 5
2. Assessment of Forest Cover Dynamics 6
2.1 Data collection 8
2.2 Methodology 9
2.3 Results 9
2.4 Accuracy Assessment 16
2.5 Detection of the reasons for the changes in forest cover 18
3. Assessment of the impacts of forest cover changes on water quality of the Lake Sevan 19
3.1 Data collection 19
3.2 Methodology development 19
3.3 Results 25
3.4 Assessment of the impacts of waterlogged forests on water quality of the lake 29
Conclusions 30
Recommendations 30
References 31

List of Abbreviations

Abbreviation	Definition
ACE	Acopian Center for the Environment
AUA	American University of Armenia
EPMB	Environmental protection and mining inspection body
FAO	The Food and Agriculture Organization of the United Nations
MMU	Minimum mapping unit
NDVI	Normalized difference vegetation index
NP	National Park
RA	Republic of Armenia
SNCO	State non-commercial organization
UAV	Unmanned aerial vehicle

Executive summary

1.1 Introduction and Background

Lake Sevan's basin, the Armenian pilot site of the PONTOS project, with the area of about 4900 km^2 is located in the Gegharkunik region. The significant part of the forests is placed on the territory of the "Sevan National Park" SNCO, which are artificial forest plantations founded on the drained areas of the former lake bottom as a result of lowering of the lake level. The main forest-forming tree species in the basin are pine, poplar, willow and acacia, and all over the basin there are also impassable bushes of sea buckthorn. There were several reasons for the establishment of the forests around the lake. First of all after the artificial lowering of the lake level in order to use the water of the lake Sevan to irrigate the arid lands of the Ararat valley and generate hydropower for the development of the Armenian economy, hectares of forests were planted in drained areas to stabilize the coastal soils and to reduce the entry of the erosive materials and mineral elements into the lake. The second reason was the creation of the recreation area for the population of RA.

Later, since the lowering of the lake level during the 20th century had serious consequences for the physical, chemical and biological characteristics of the lake, the decision was made to raise the level of the lake, which prompted the emergence of a new issue- the waterlogging of the green coastal zone of the lake. Accordingly, in order to prevent the deterioration of water quality, cleaning of the coastal areas covered with vegetation started in 2015 (cleaning works are still ongoing).

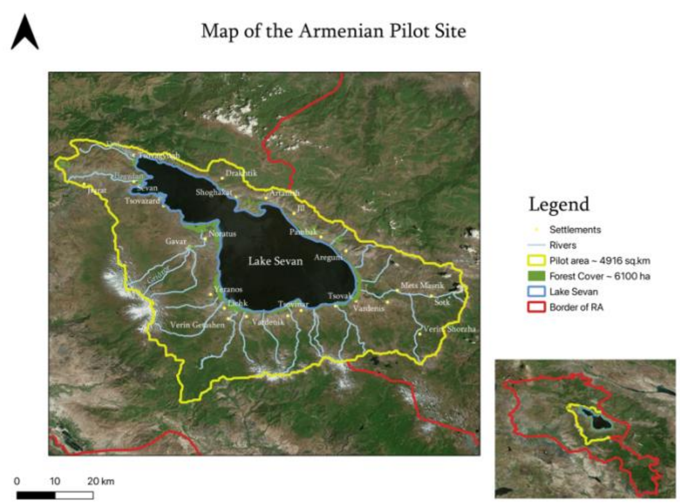


Figure 1 – Armenian Pilot Site

1.2 Purpose of the assessment

The purposes of this assessment are to:

- Monitor the dynamics of tree cover loss and gain in the Lake Sevan basin during the period of 2009-2019 using the PONTOS platform,
- Assess the impact of forest cover changes and its consequences of Lake Sevan.

1.3 Literature review

A literature review was conducted to collect background information on the forests of the pilot site and to investigate the international experience on methodologies of the assessment of forests on water quality. Sources of the literature review included national and international reports, laws, government decisions and published articles in professional journals.

The Armenian pilot site completely includes the territory of the "Sevan" National Park. According to the reviewed literature on the territory of "Sevan" National Park, forest inventory work was carried out first in 1962, then periodically in 1972 and 1983. In 2005 as part of the development of a NP's management plan, the adjustment of forest boundaries has also carried out using GIS. According to the source mentioned above, the forest cover of the NP in 2005 was 13250.2 ha, which is 1285.2 ha more, then the area recorded in 1983. The mentioned growth in the forest area was not only associated with the plantation of artificial forests, but also with an increase in the areas of shrubs with a high trunk-growth potential (sea buckthorn, yellow acacia), which have been also observed in the basin present time. This assessment provides an opportunity to understand the situation related to forests in the pilot area in recent years. As part of the assessment the forest covers for several years were calculated and the changes in the forest cover over period 2009-2020 were monitored using satellite imagery.

The review of the literature on the assessment of the forest impacts on the water quality revealed that the relationship between forest and water is influenced by a large array of factors, primarily climate, topography, soil, forest structure and composition, as well as forest management (FAO 2013, Brown et al. 2005). It has also become clear, that despite the general recognition of the importance of forests for the water cycle, the relationships between forests and water in a particular context are little known (van Dijk and Keenan 2007). However, as noted in one of the studies, evidence suggests that forest cover can confer benefits with regards to water quality (Bauhus et al., 2010; Townsend et al., 2012; van Dijk and Keenan, 2007), as forests contribute to climate regulation, protection of water resources, and reduce the flow of harmful mineral elements into the lake. Within the framework of this assessment an attempt was also made to evaluate the impact of the changes in forest cover of the pilot area on water quality of Lake Sevan, combining the results of forest monitoring with in-situ data on water quality.

2. Assessment of Forest Cover Dynamics

As previously mentioned, the forest cover of the Lake Sevan basin is mainly characterized by coniferous and broad-leaved forests and impenetrable sea buckthorn bushes. Considering the definition of the forests described in the Forest Code of the RA, at the beginning of this study decision was made to separate the main forest-forming tree species from the widely spread sea buckthorns bushes on the satellite imagery. For this purpose, several field visits to the pilot area were carried out, numerous samples were taken from broad-leaved and coniferous forest tree species (Figure 2, 3, 4, 5), as well as from the sea buckthorn bushes. After the supervised classification it became clear that it is not feasible to separate bushes from trees because of the low resolution of the satellite images used and the same pixel values of the broad-leaved forests and bushes of sea buckthorn (so it was decided to include the bushes to the forest cover).

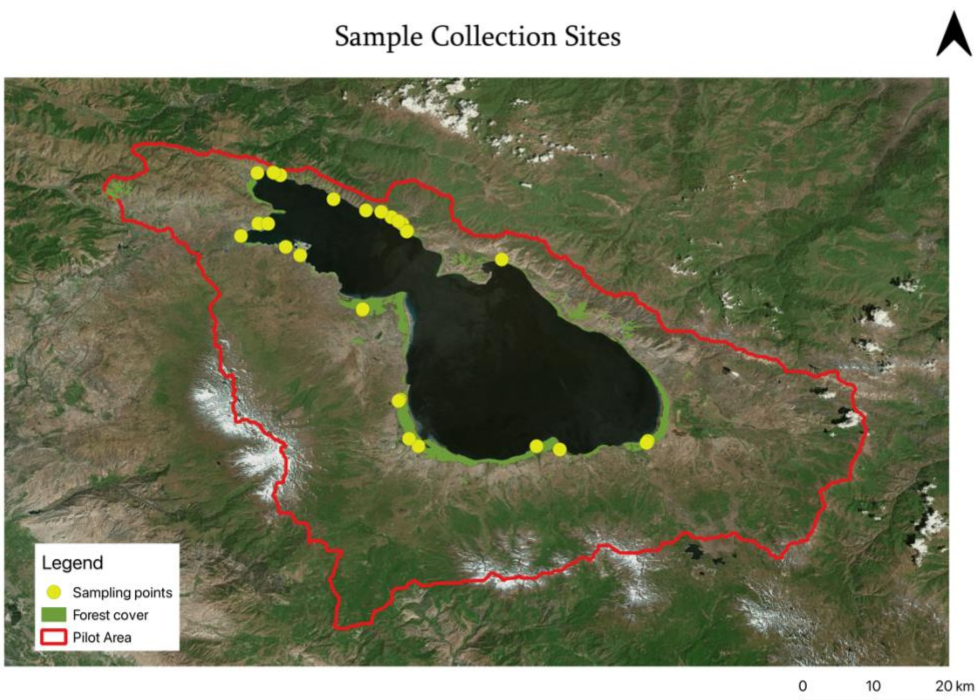


Figure 2. Sample collection sites

Figure 3. Sea buckthorn bushes

Figure 4. Pine forest

Figure 5. Broad-leaved forest

2.1 Data collection

Sentinel-2 (A,B), Landsat 8, Landsat 7 and Landsat 5 imagery has been used for the implementation of the assessment of the forest cover changes for the period of 2009-2020 (Table 1). The dates of the satellite images were chosen to represent the same vegetation state in different years. A number of preprocessing steps were performed for the preparation of the imagery for the forest cover assessment.

Table 1. List of the satellite images used for the assessment

N	Satellite	Resolution	Dates
1.	Landsat 5	30 m	06/07/2009
2.	Landsat 5	30 m	22/07/2009
3.	Landsat 5	30 m	10/08/2010
4.	Landsat 5	30 m	29/08/2011
5.	Landsat 7	30 m	24/09/2012
6.	Landsat 8	30 m	03/09/2013
7.	Landsat 8	30 m	06/09/2014
8.	Landsat 8	30 m	08/09/2015
9.	Sentinel-2 (TMK, TNK)	10 m	15/08/2016
10.	Sentinel-2 (TMK, TNK)	10 m	30/08/2017
11.	Sentinel-2 (TMK, TNK)	10 m	30/08/2018
12.	Sentinel-2 (TMK, TNK)	10 m	15/08/2019
13.	Sentinel-2 (TMK, TNK)	10 m	20/07/2020
14.	Sentinel-2 (TMK, TNK)	10 m	13/09/2020

The following software programs have been used during the assessment: QGIS, ArcMap, ENVI, SNAP, Google Earth and Agisoft Metashape. Given the fact that satellite images with different resolutions were used during the assessment, the satellite images were resampled, but unfortunately, differences in resolutions significantly affected the outcome. For the validation of results, several field trips were implemented, Google Earth and UAV images were used.

2.2 Methodology

The methodology for the separation of bushes and forests is the sequence of the following steps:

- Geocoded data collected during the field visits were entered into GIS (samples of sea buckthorn, pine and broad-leaved trees).
- Based on the imported data and calculations of vegetation indices (NDVI, SAVI), supervised classification was carried out (MMU>= 0.1 ha), false color and other band compositions were also used.
- As a result, it turned out that the pixel values of the vegetation indices of broad-leaved trees and bushes appear in the same range, which causes problems in the separation.

For the assessment of the forest cover loss following methodology has been used:

- NDVI values were calculated for consecutive years (2009 – 2020) for each available satellite image.
- Derived NDVI layers were subtracted from each other (e.g. (2018_NDVI) – (2017_ NDVI) and negative pixel values were selected for the identification of changes in forest cover.
- Extracted changed areas were separated using the method of semi-automatic classification and visual interpretation.
- Final layers were combined with the layer of the “Sevan National Park” to obtain the recorded changes over the years for each Branch and Section of the park.

2.3 Results

The results are illustrated in Table 2 below (the table only includes information on forest cover loss).

Table 2. Forest cover loss during the period 2009-2020 for each section of "Sevan" NP

	Branch	Section	Year	Change (ha)
1.	Sevan	Axtamar	2009-2020	5,72
2.	Sevan	Sevan	2009-2020	3,47
3.	Noratus	Ayrivan	2009-2020	101,98
4.	Noratus	Noratus	2009-2020	138,78
5.	Noratus	Gavar	2009-2020	9,48
6.	Martuni	Yeranos	2009-2020	19,41
7.	Martuni	Martuni 1	2009-2020	22,92
8.	Vardenik	Martuni 2	2009-2020	16
9.	Vardenik	Vardenik	2009-2020	7,19
10.	Vardenik	Tsovinar	2009-2020	46,25
11.	Vardenis	Vardenis	2009-2020	100,95
12.	Vardenis	Tsovak	2009-2020	37,68
13.	Arevik	Areguni	2009-2020	-
14.	Arevik	Pambak	2009-2020	0,13
15.	Artanish	Artanish	2009-2020	0,34
16.	Artanish	Drakhtik	2009-2020	0,33
Total Change		**510,7 ha**		

Figure 6. Forest cover loss during 2019-2020

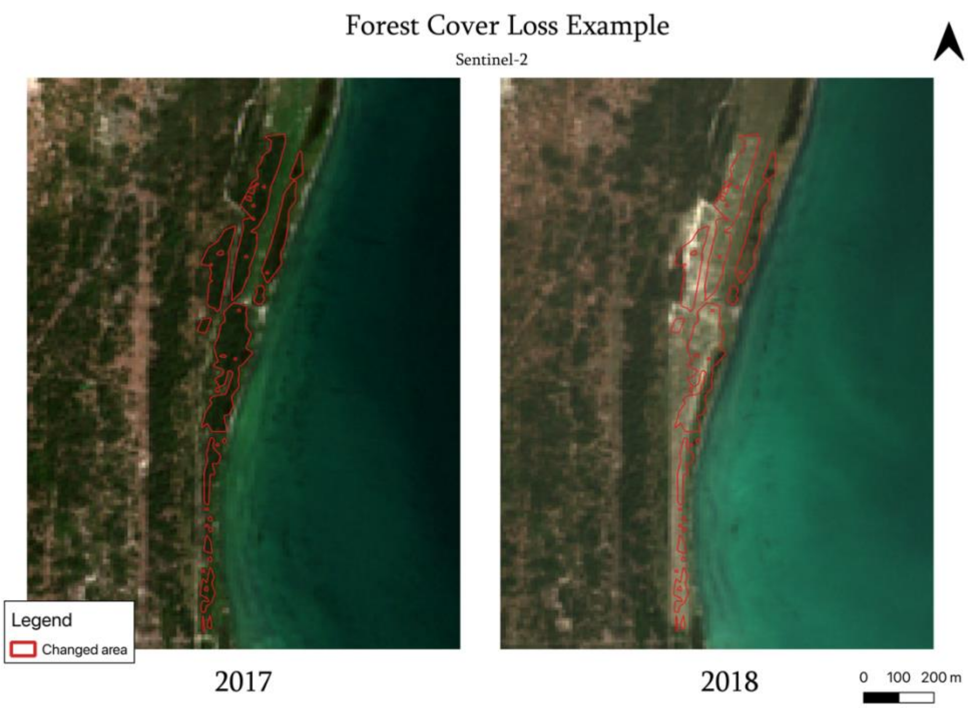
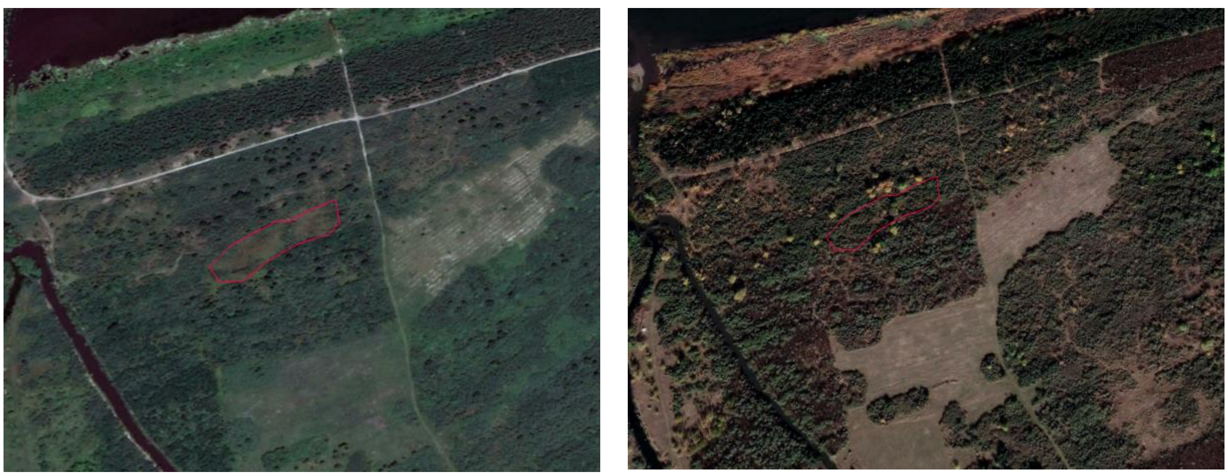


Figure 7. Forest cover loss during 2017-2018

Some observations were made in order to estimate the gain in forest cover, which was based on the same methodology as in the case of forest cover loss, but this time, positive values (instead of negative) of the vegetation index were highlighted. For the implementation of the forest cover gain 2013 Landsat 8 and a 2020 Sentinel-2 satellite images were used. The results mostly coincided with the reed beds, grasslands and shrubs, which became clear in the validation process, while checking the results with the high resolution drone imagery, so it was decided not to publish the results.

Below you can see an example of a forest cover gain analysis showing an increase in shrub habitat which was also discovered during mention process (Figure 8).



2010 ***2019***

Figure 8. Increase in shrub habitat

In addition, it is important to note that the reforestation works that has been carried out in the pilot area in recent years can be barely noted on satellite images, since it takes at least 15 years to shift the new plantations into forest category.

Within the framework of the assessment the forest cover detection of the pilot area for several years was also implemented. For the estimation of the forest cover for 2013 Landsat 8 images were used. Detection of the forest cover of 2016 and 2019 was done based on the Sentinel-2 imagery. The estimation of the forest cover was implemented by supervised classification of satellite images using true and false color band compositions. The results were corrected by visual interpretation method, using UAV images and Google Earth. Forest Cover areas of the Lake Sevan's basin for 2013, 2016, 2019 are presented in Table 3.

Table 3. Forest cover areas in 2013, 2016 and 2019

Year	Forest Cover (ha)
2013	6111,8
2016	6077,6
2019	6054,2

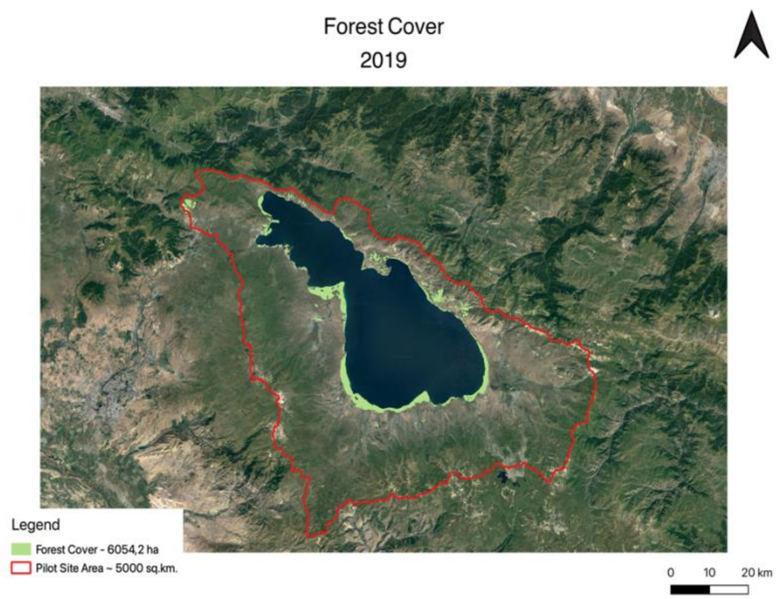


Figure 9. Forest cover of the pilot area for 2013

Figure 10. Forest cover of the pilot area for 2016

Figure 11. Forest cover of the pilot area for 2019

It's also very important to note that the forest cover of the Armenian Pilot Site is only a part of the forest cover of the Gegharkunik region.

Figure 12. Armenian pilot site and the forest cover of the Gegharkunik region

2.4 Accuracy Assessment

To validate the results obtained from satellite images, UAV images for 2017 - 2020 and reference data collected from the field were used. The circles shown on Figure 13 denote the validation points.

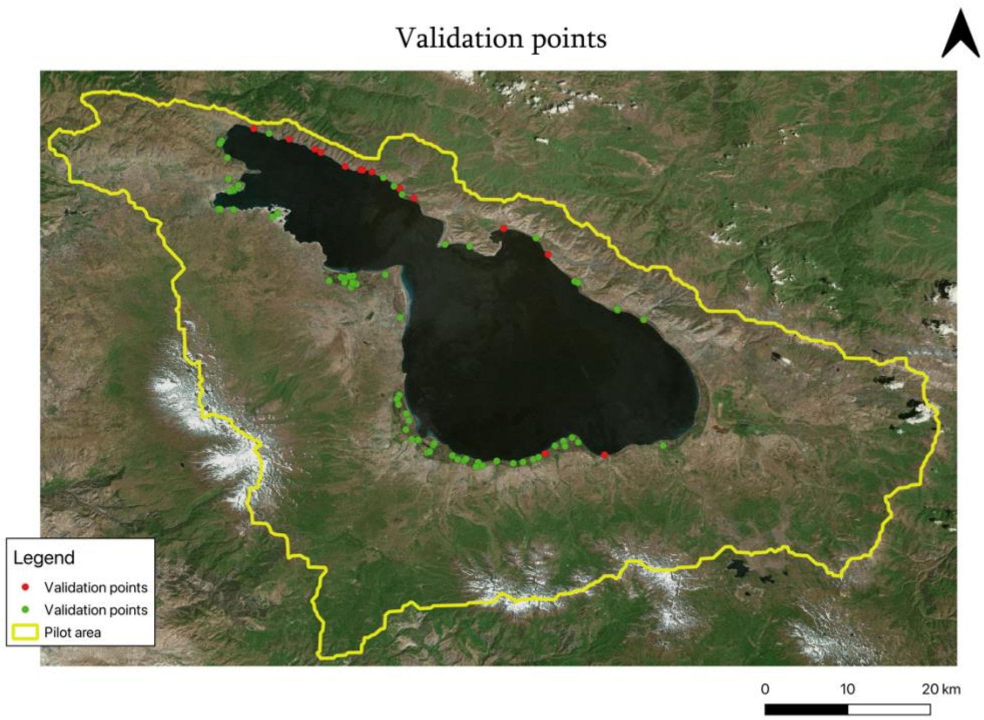


Figure 13. Map of the validation points

After the classification of the satellite images (forest / non-forest) each selected pixel (resolution 10m or 30m) has been compared with the relevant pixels of the drone image (resolution < 10 cm) or with the points collected from the field to determine the accuracy of the results.

Table 4. Accuracy assessment

Total number of samples	89
Valid points	74
Non - Valid points	15
Accuracy	**83.1 %**

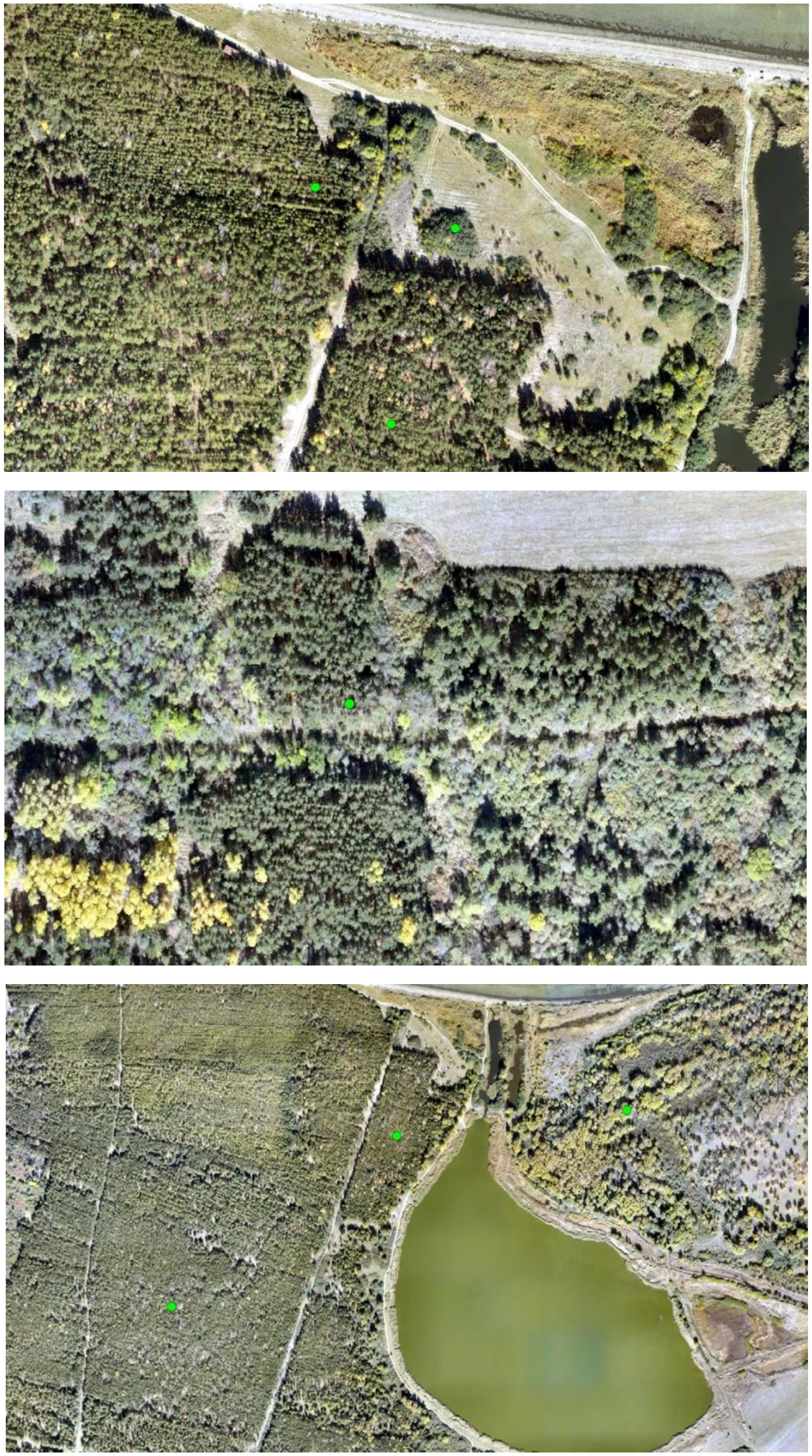


Figure 14. UAV images and validation points used during validation process

2.5 Detection of the reasons for the changes in forest cover

Data collected from the “Sevan National Park” by the EPMB (Environmental protection and mining inspection body) partners were used for the identification of the purposes of the forest cover loss. The copies of the forest cutting coupons and other related documents were analyzed for the identification of the purposes of changes. The figure 15 shows the example of forest cutting coupon for 2019, where we can find information about the location, types, volumes and numbers of felled trees, but the noted location is only highlighting the section and the brunch (Ayrivan Section, Figure 16) of the national park, not the exact coordinates.

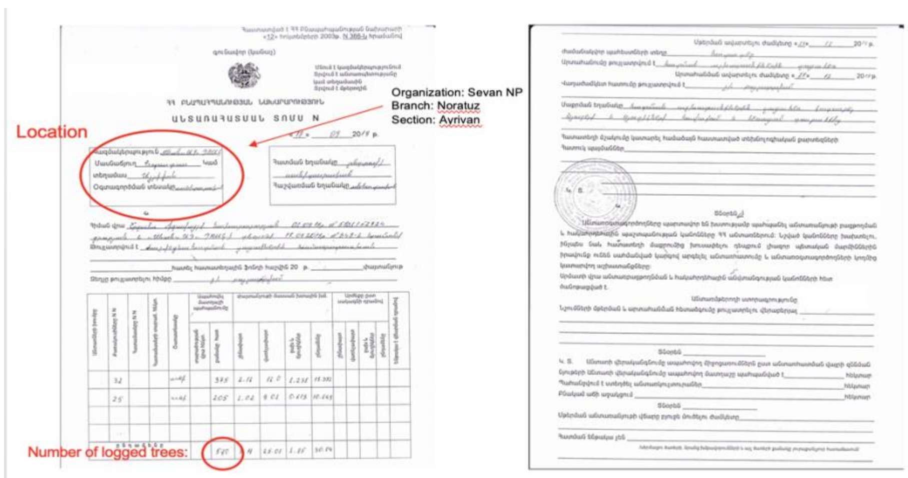


Figure 15. Example of forest cutting coupon

Figure 16. “Ayrivan” Section of the “Sevan” NP

So, as the documents were not georeferenced (exact coordinates were missing), the comparison of the forest cutting coupons with data gathered from satellite images was not feasible.

3. Assessment of the impacts of forest cover changes on water quality of the Lake Sevan

In this study, we also attempted to assess the impact of changes in forest cover on water quality. The steps carried out for the comparison of forest cover change data and water quality monitoring data are presented below:

3.1 Data collection

Water quality data was provided by the “Hydrometeorology and monitoring center” SNCO. During the assessment accessible data from all water quality points of observation of Lake Sevan for 2009-2020 was used. Data from 40 (including points for different depths) observation points were used during the study. An attempt was made to find a correlation between the change in forest cover and several water quality indicators:

- Dissolved oxygen,
- pH,
- Phosphate ion,
- Ammonium ion,
- Nitrite ion,
- Nitrate ion.

Indicators that could be affected by forest cover were chosen on the basis of the studied literature and analysis of the situation in the basin. During water quality data analysis it became clear that information about water quality is not periodic.

3.2 Methodology development

1. At the first stage, in order to study the relationship between forest cover and water quality, it was decided to collect periodic monitoring information on water turbidity. Unfortunately data periodicity was insufficient for the comprehensive implementation of the analysis.
2. Due to the lack of information on dissolved oxygen it was decided to remove that information from the results as well.
3. In order to compare data from different observation points and changes in forest cover, as well as to obtain accurate correlations between them, it was decided to group the

sections of the "Sevan National Park" with the corresponding observation points. The distribution table and relevant figures are shown below:

Table 5. Nearest water quality observation points for each section of "Sevan" NP

	Branch	Section	Nearest monitoring points
1.	Sevan	Axtamar	116, 117, 130-PS, 130'-PS
2.	Sevan	Sevan	115, 127-PS, 127'-PS, 131
3.	Noratus	Ayrivan	126-PS, 126'-PS, 130
4.	Noratus	Noratus	124-MS, 124'-MS, 130
5.	Noratus	Gavar	128
6.	Martuni	Yeranos	128, 129
7.	Martuni	Martuni 1	127,128,129
8.	Vardenik	Martuni 2	127,129
9.	Vardenik	Vardenik	127,129
10.	Vardenik	Tsovinar	119-MS, 119'-MS, 125, 126
11.	Vardenis	Vardenis	119'-MS, 124, 125
12.	Vardenis	Tsovak	118-MS ,118'-MS, 121, 123, 124
13.	Arevik	Areguni	118'-MS, 121, 122,

			123
14.	Arevik	Pambak	115-MS, 115’-MS, 122
15.	Artanish	Artanish	115-MS, 115’-MS, 119, 120, 124’-MS,
16.	Artanish	Drakhtik	118, 119, 131’-PS, 131-PS,

Table 6. Years of observations for each water quality observation point

Number of the observation point	Observation dates
115	2009, 2010, 2011, 2012, 2015, 2016, 2017, 2018
115’	2016, 2017, 2018
116	2009, 2010, 2011, 2012, 2015, 2016, 2017, 2018
116’	2016, 2017, 2018
117	2009, 2010, 2011, 2012, 2015, 2016, 2017, 2018
117’	2016, 2017, 2018
118	2009, 2010, 2011, 2012, 2013
118’	2016, 2017, 2018
118 MS	2019, 2020, 2021
118’ MS	2019, 2020, 2021

119	2009, 2010, 2011, 2012, 2015, 2016, 2017, 2018
119’	2016, 2017, 2018
119 MS	2019, 2020, 2021
119’ MS	2019, 2020, 2021
120	2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018
120’	2016, 2017, 2018
121	2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018
121’	2016, 2017, 2018
122	2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018
122’	2016, 2017, 2018
123	2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018
123’	2016, 2017, 2018
124 MS	2019, 2020, 2021
124’ MS	2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018
124’	2019, 2020, 2021
125’	2016, 2017, 2018
126’ MS	2019

126’ PS	2019, 2020, 2021
126’	2016, 2017, 2018
127 PS	2020, 2021
127’ PS	2019, 2020, 2021
127’	2016, 2017, 2018
128’	2016, 2017, 2018
129’	2016, 2017, 2018
130 PS	2019, 2020, 2021
130’ PS	2019, 2020, 2021
130’	2016, 2017, 2018
131 PS	2019, 2020, 2021
131’ PS	2019, 2020, 2021
131’	2016, 2017, 2018

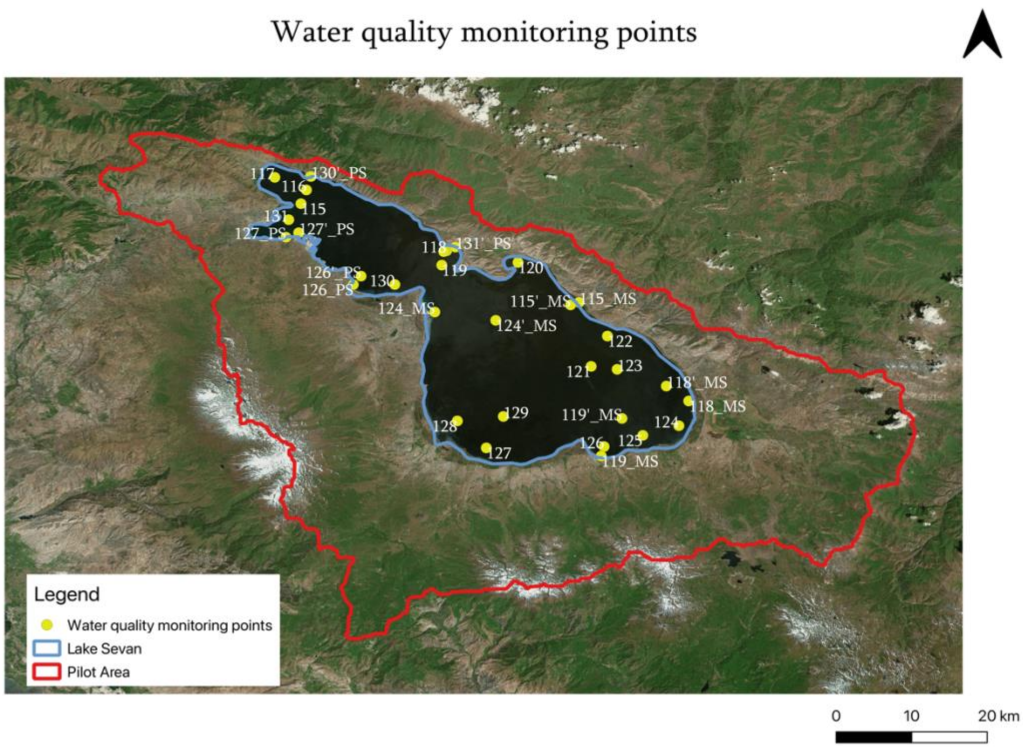


Figure 17. Water quality observation points of the Lake Sevan

Figure 18. Map of the “Sevan” National Park

4. After several analyses, it became clear that data on water quality monitoring, as well as changes in forest cover in some areas are not periodic (Table 6), and in some cases are not available at all, therefore, the data from all sections were averaged and calculated for the entire lake.

3.3 Results

Thus, the constructed correlations between water quality and forest cover loss showed that the loss in forest cover had almost no effect on the water quality in the lake. The correlation coefficients for all components are very low (except for phosphates, r = 0.4, which also does not meet the established standards), i.e. connection does not exist (Figure 19, 20, 21, 22, 23 Table 7).

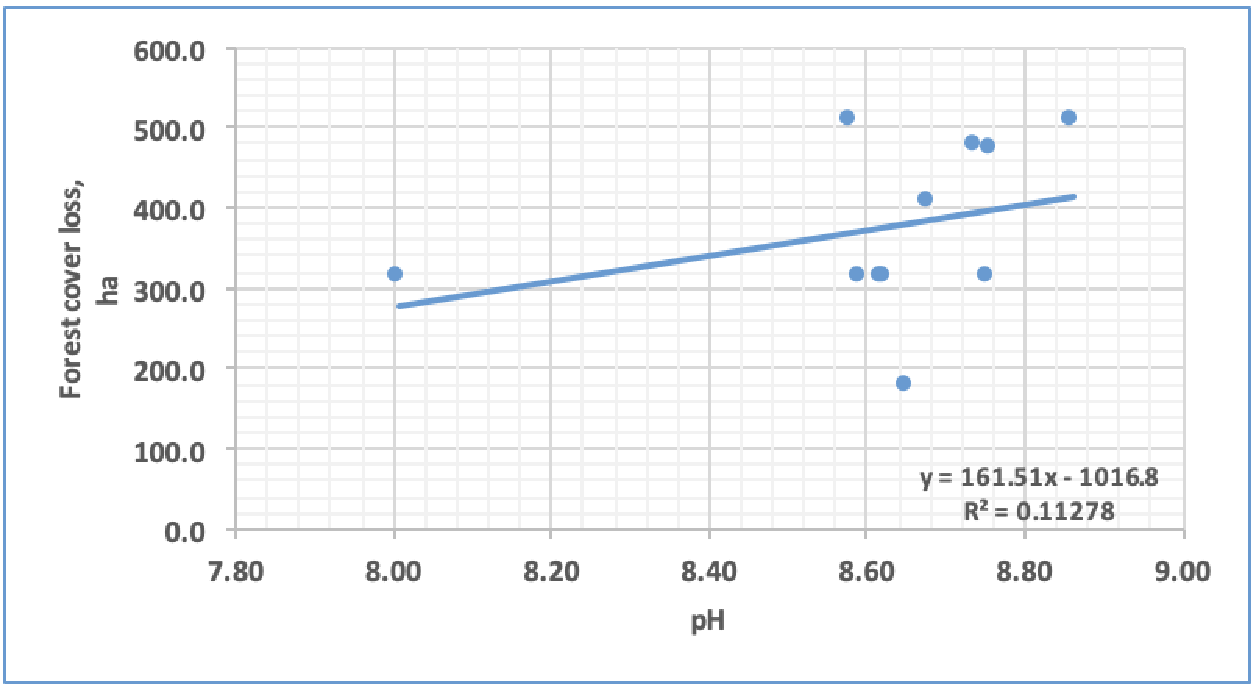


Figure 19. Correlation between pH and forest cover loss

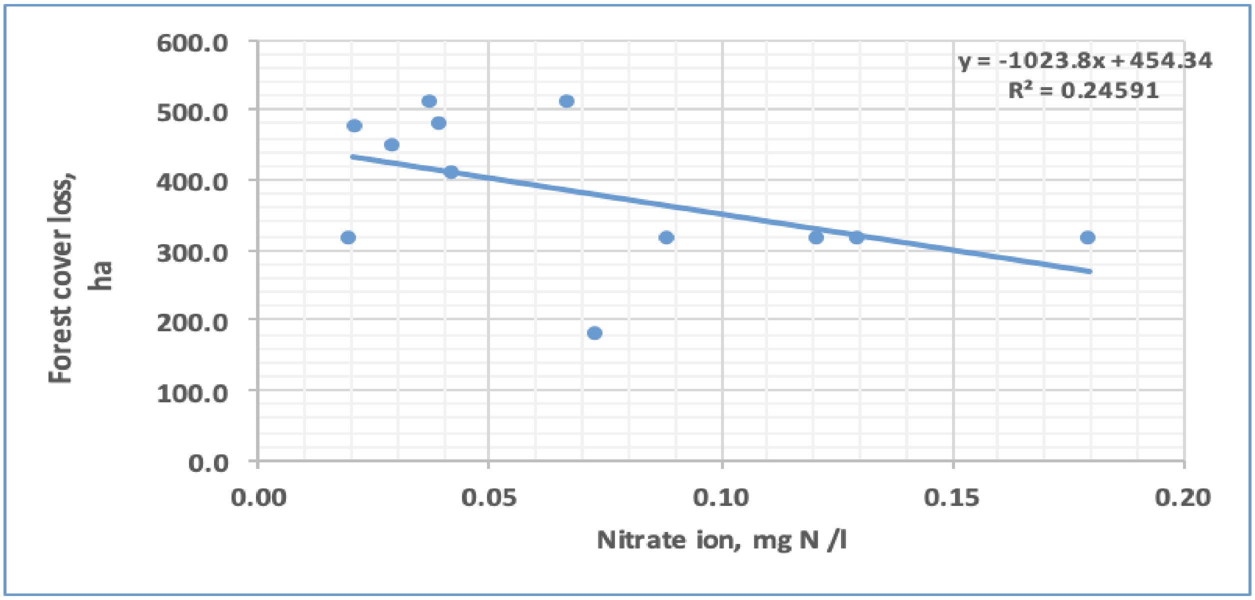


Figure 20. Correlation between Nitrate ion and forest cover loss

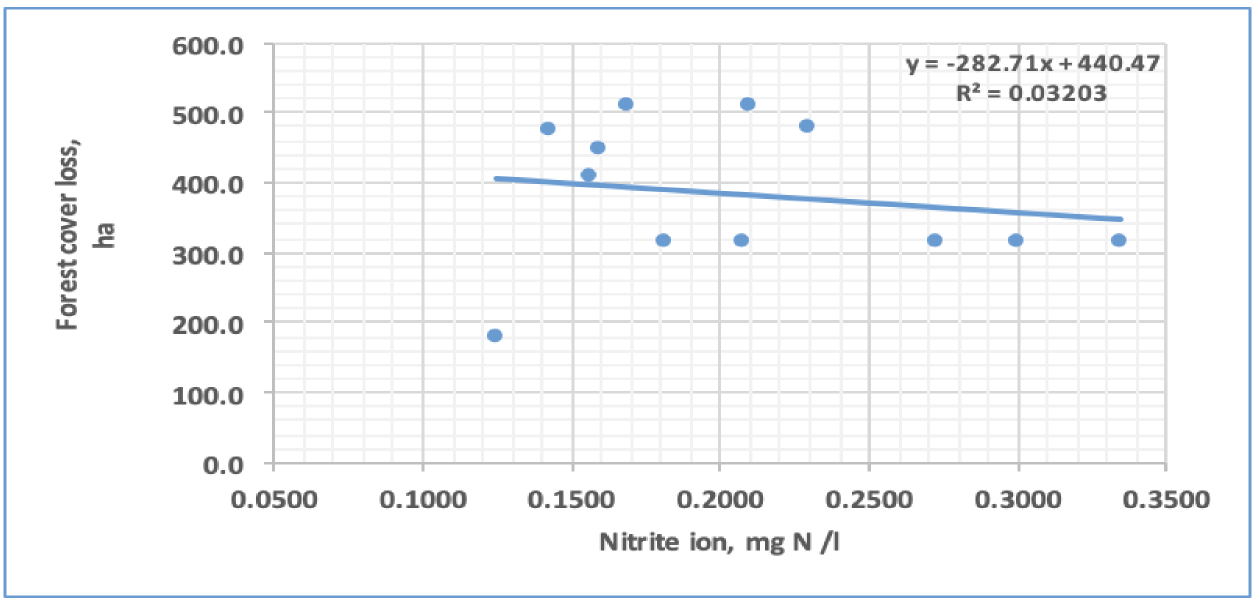


Figure 21. Correlation between Nitrite ion and forest cover loss

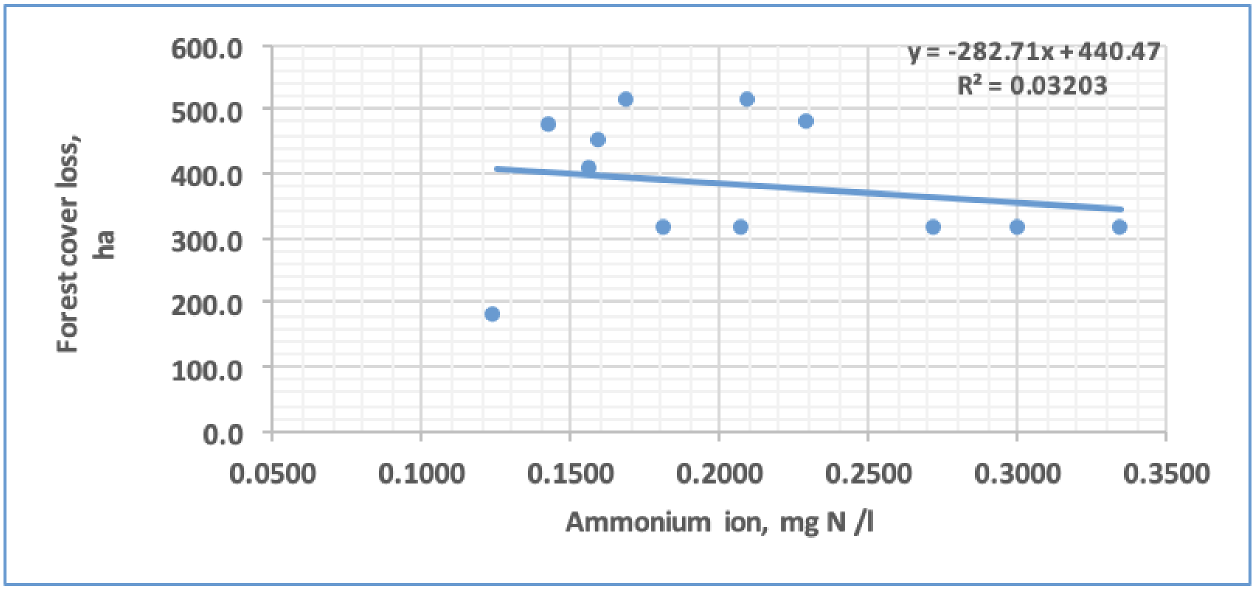


Figure 22. Correlation between Ammonium ion and forest cover loss

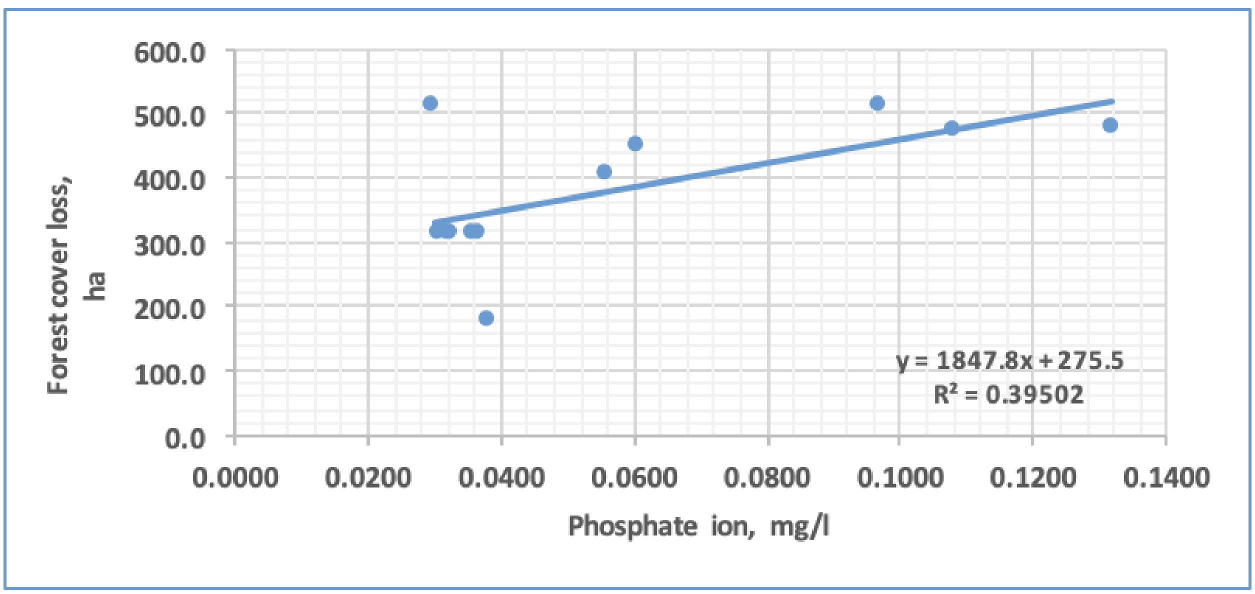


Figure 23. Correlation between Phosphate ion and forest cover loss

Table 7. Correlation Formulas and Reliability Coefficients of some Indicators of Lake Sevan's Water Quality and Forest Cover Loss

Water quality indicators	Correlation Formulas	Reliability Coefficients, R^2
1	2	3
pH	y = 161.51x - 1016.8	0.1128
Nitrate ion	y = -1023.8x + 454.34	0.2459
Nitrite ion	y = -2135.8x + 387.17	0.0005
Ammonium ion	y = -282.71x + 440.47	0.032
Phosphate ion	y = 1847.8x + 275.5	0.395

3.4 Assessment of the impacts of waterlogged forests on water quality of the lake

The detection of the areas with waterlogged trees was implemented during the assessment of forest cover. The layer of the vegetation located in the water, obtained from the forest cover assessment, was excluded from the results, as during the validation process it turned out that the vegetation found mostly coincides with the ridges (the layers were excluded, on the condition that later it should be compared with the results of the other related assessments of the Pontos project, to avoid the overlaps between waterlogged forest data and floating vegetation). However, during the comparison of the results gained from the satellite images with high resolution imagery, two areas with waterlogged forests were identified. Therefore, attempts have been made to assess the impact of the waterlogged forests on water quality.

Figure 24. Waterlogged forests

Since the water quality monitoring data of the nearest observation points was too short (3 years), the results obtained were not reliable (Figure 24).

Conclusions

- The results of the forest cover estimation and changes in forest cover are approximate due to the resolution of the satellite images used.
- Total 510,7 ha forest cover loss occurred during the period 2009-2020 in the pilot area.
- Water quality monitoring data are not periodic. There are a number of missing data that also significantly affect the quality of the final result of the assessment.
- Correlations between water quality and forest cover loss showed that the loss in forest cover had almost no effect on the water quality in the lake.
- Even if correlations were found, this would not mean that these changes in water quality have occurred due to the changes in forest cover itself, because external factors (such as sewage, fertilizers, lake level changes, climate change, etc.) have a greater impact on water quality, rather than simply observed changes in forest cover.
- A comparison of the forest cover loss data with the coastal cleaning data provided by the “Sevan National Park” suggests that changes were mainly associated with the clearing of coastal forests. Its impact on water quality can definitely be assessed as positive, since if these forests were to be waterlogged in the future, this would further worsen the ecological state of the lake.

Recommendations

- It is essential to ensure the periodicity of monitoring data for water quality indicators to ensure the quality of future studies and the implementation of comprehensive forecasts.
- It is necessary to include geocoded information (exact coordinates) into the forestry protocols of the “Sevan National Park " in order to simplify the works, assist sustainable forest management, implement forecasts and reach other essential goals.
- In order to obtain updated qualitative and quantitative precise data on the forests of the “Sevan” National Park, it is necessary to carry out forest inventory works.

References

1. Anthropogenic Transformation of Lake Ecosystems and Existent Problems (Case Study of Lake Sevan), Travel Vardanyan, Yeva Danielyan, Zohrab Muradyan, 2021
2. DECISION OF THE GOVERNMENT OF THE REPUBLIC OF ARMENIA On Approving Program on Establishing New Forest Layer around Lake Sevan (2014-2023), 2012
3. Decision of the government of the Republic of Armenia on the approval of the 2007-2011 management plan of "Sevan" National Park, 2007, January , N 205-N
4. Forest Code of the Republic of Armenia, 2005
5. Lake Sevan, Experience and Lessons Learned Brief, Araik Babayan, Susanna Hakobyan, Karen Jenderedjian, Siranush Muradyan, Mikhail Voskanov, 2006
6. Law about Approval of Annual and Complex Measures on Conservation, Restoration, Reproduction and Use of the Ecosystem of Lake Sevan, 2001
7. Law of the Republic of Armenia "About the Lake Sevan", 2001
8. Managing Forests for Water Quality: Streamside Management ZonesBarbara Daniels, Darren McAvoy, Mike Kuhns, Ron Gropp, 2017
9. Managing Forests for Water Quality:Forest RoadsBarbara Daniels, Darren McAvoy, Mike Kuhns, Ron Gropp, 2007
10. Modeling and cost valuation of ecosystem services of forest geosystems (the case of Tavush Marz), Gorik Avetisyan, 2018
11. NON-REGULATED AND ILLEGAL LOGGING IN ARMENIA AND ITS CONSEQUENCES, H. SAYADYAN
12. Planted forests and water in perspective Albert I.J.M.van DijkaRodney J.Keenanb, 2007
13. The Hydro-Chemical Changes of Lake Sevan Water After the Artificial Lowering of the Water Level, Travel Vardanyan, 2009
14. The impact of forestry as a land use on water quality outcomes: An integrated analysis,Colm Duffya Cathal O'Donoghueb Mary Ryanc Kevin Kilclinec Vincent Uptonc Charles Spillanea, 2019
15. The self-regeneration abilities of lake sevan basin natural landscapes and nature conservation issues, H. Sayadyan, 2013
16. Water Quality and Forest Management, Robin G. Pike, Michael C. Feller, John D. Stednick, Kevin J. Rieberger, Martin Carver 2010
17. Water Quality and Forest Management. R.G. Pike, T.E. Redding, R.D. Moore, R.D. Winkler, K.D. Bladon, January 2010