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Lago Grande in Monticchio Area (Southern Italy): Integrating Multitemporal Airborne Images, Satellite Images (Sentinel-2) and Historical Data to Assess the Extent of Nymphaea Alba l and Taxodium Distichum (l.) Rich in Natural Habitats of Directive 92/43/EEC

Spicciarelli Renato[1], Miraudа Domenica[2] and Mancino Giuseppe[3]
[1]Basilicata University, School of Agricultural, Forest, Food and Environmental Sciences, V.le Ateneo Lucano, 10, 85100 Potenza (Italy); email: renato.spicciarelli@unibas.it
[2]Basilicata University, School of Engineering, V.le Ateneo Lucano, 10, 85100 Potenza (Italy); email: domenica.mirauda@unibas.it
[3]Centro di Geomorfologia Integrata per l'Area del Mediterraneo, Via Francesco Baracca, 175, 85100 Potenza (Italy)
* Correspondence: Mancino Giuseppe E-mail : g.mancino@cgiam.org
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Lago Grande and Lago Piccolo are famous species of Monticchio (Monticchio Lakes) that lie in the collapsed caldera of the volcanic structure of Mt. Vulture (Southern Italy). The entire lake area is the part of the "Monte Vulture" Special Area of Conservation (SAC IT9210210, site code in Natura2000 Network). The main purpose of this research was to verify the expansion of these two species in Lago Grande of Monticchio: Nymphaea alba L., in the Habitat 3150, and Taxodium distichum (L.) which is rich in the Habitat 91E0 (Habitat codes in Directive 92/43/EEC). Multitemporal analysis of aerial Red-Green-Blue (RGB) photographs were acquired for the years 2002 to 2015 to identify a continuous increase of the laminate of N. alba. The evolution of T. distichum which has been analyzed using multi-temporal images, documents and Sentinel-2 remotely sensed datasets. In first, the N.alba population was observed with increasing its span upto 30 percent of the lake area. In 2011, it occurred emissary obstruction. From this year, the specie population was declines up to 24 percent of the lake area. The large surface area occupied by the laminate can bring about to a considerable reduction of the characteristic species of Habitat 3150. In 2017, T. distichum has expanded over an area of 8047 square meters. The evolution of this species reveals the risk of habitat 91E0*reduction with consequences on the population of the moth*

Brahmaea (Acanthobrahmaea) europaea Hartig and an Italian endemic species with an exceedingly restricted distribution. The working methodology is based upon combination of different informative source (satellite images, multitemporal airborne images and historical datasets) to identifying vegetation dynamics occurred in hydrophytic vegetation, wetlands and riparian habitat of Lago Grande of Monticchio.

Keywords: Biological invasions; Multitemporal historical data; Sentinel-2, K-means clustering; Monticchio lakes.

INTRODUCTION

In Europe, the aquatic and riparian environments are among the most threatened habitats by human disturbances [1, 2, 3, 4] and invasive alien species are at present a major focus of international conservation concern and the subject of cooperative international efforts, such as the Global Invasive Species Programme (GISP) [5]. Several plant species, wetlands and riparian habitats provide very interesting examples of biological invasions after their emergence in natural ecosystems into new geographical regions [6, 7, 8, 9, 10]. Floating-leaved plants, particularly nymphaeids are often the dominant vegetation in shallow water [11, 12, 13]. The importance of water level fluctuations in regulating aquatic plant distribution and composition has been demonstrated in numerous lakes [13, 14, 15, 16, 17, 18]. Some studies highlight the effects on Bald Cypress [19, 20, 21, 22, 23, 24] but we have very less knowledge about the response of nymphaeids to relatively small changes in water level in natural habitats [24, 25, 26, 27]. Specific studies and regional surveys on the invasion by non-native species have a great importance to monitor and manage the natural resources, particularly in wetlands.

The increasing N. alba population may cause a reduction to the characteristic species of the Habitat 3150 such as *Ceratophyllum demersum* L., *Myriophyllum spicatum* L., *Potamogeton lucens* L., *P. crispus* L. *T. distichum* trees, *Fraxinus angustifolia* subsp. *oxycarpa* (Willd.) and other oleaceae in Habitat 91E0. These species are host plants of *Brahmaea europaea* Hartig and the most outstanding Italian moth species with exceedingly restricted range; in fact, this butterfly occurs only in a very small area, mainly around Mount Vulture [28, 29].

In order to evaluate fluctuations over time in *Nymphaea alba*, spatio-temporal images were used, especially from the Google Earth Pro platform. Moreover, the Google Earth image archive is recognized and used for scientific purposes which initially concerns with temporal changes in landcover [30] and identification of potential habitats suitable for some species [31]. The current version of the Google Earth Pro® platform is available to provide (http://earth.google.com/download-earth.html) historical images with different frequencies depending upon the geographic area. Therefore, the validation tool provided in Google Earth [32, 33], is suitable for analysis of extension in particular land use classes [34, 35,36, 37, 38, 39]. For the assessment of the geographical location of *Taxodium distichum*, remotely sensed images from Sentinel-2 satellite have been used to map land use features [40, 41, 42, 43] and for the particular landuse dynamics [44, 45].

This research aims at developing a working methodology which is capable to monitor the expansion in populations of two species *Nymphaea alba* L., in Habitat 3150 and *Taxodium distichum* (L.) in the Habitat 91E0 (Southern Italy). It also aims at considering the rise in lake level since 2011. The species surviving in these environments are at risk, so it is significant to include in Special Area of Conservation (SAC) IT9210210 "Monte Vulture" (site code in Natura2000 European Network) inserted in the newly established Regional Natural Park of Vulture.

Study area

Lago Grande (LG) di Monticchio and Lago Piccolo di Monticchio (LP) are two adjacent maar lakes of Monticchio (40°55'N, 15°35'E), within a caldera on the western slopes of Mount Vulture in Basilicata, a part of Southern Italy. LG is the larger but less voluminous than LP. Both lakes lie within SAC "Monte Vulture" [46]. Table 1 summarizes some morphometric characteristics of the Monticchio lakes (November 2, 2015 [47]) by Spicciarelli & Miraudа (Table 1).

Table 1. Morphometric characteristics of the Monticchio lakes (Spicciarelli & Miraudа 2015).

	Lago Grande	**Lago Piccolo**
Volume (*m^3*)	3402.18	4262.83
Height (*m* asl)	652.79*	656.23
Surface (*Ha*)	41.47	15.49
Maximum depth (*m*)	39.78	44.09
Perimeter *(m)*	2379.00	1469.00
Maximum lenght *(m)*	878.24	514.55
Maximum width *(m)*	589.46	400.64

* This data is increased by one metre because of the accidental obstruction of the emissary.

The Lakes have a small drainage area (4.0 km^2), where water features are characterised by internal springs, precipitations and runoff. From LP, water comes toward LG through a short stream (length: 216 m; flow: 50 L s^{-1}). LG has two separate areas differing in morphometry as shown in Figure 1. A large area is relatively shallow and rich with macroscopic submersed vegetation and the water is mixed completely once or twice a year. It is characterised by high concentrations of ions in deeper layers. The monimolimnion is present from 20 to 40 m which becomes depleted of oxygen (less than 1 meq L^{-1}).

During summer, the high photosynthetic activity leads to O_2 oversaturation. In LG, the depth of water anoxia fluctuates between 5 m in summer and 20 m in winter, when a large portion of lake bottom, lying at 12 m depth, is oxygenated. Chemical data show a situation between eutrophic and hypereutrophic conditions, with a total P (Phosphorus) concentration frequently exceeding 50 μg L^{-1} (surface water) and a Secchi disk depth in summer of about 100-120 cm, with maximum macrophyte growing depth (MMGD) of 3.20-3.40 m, determined in September 2015 [47].

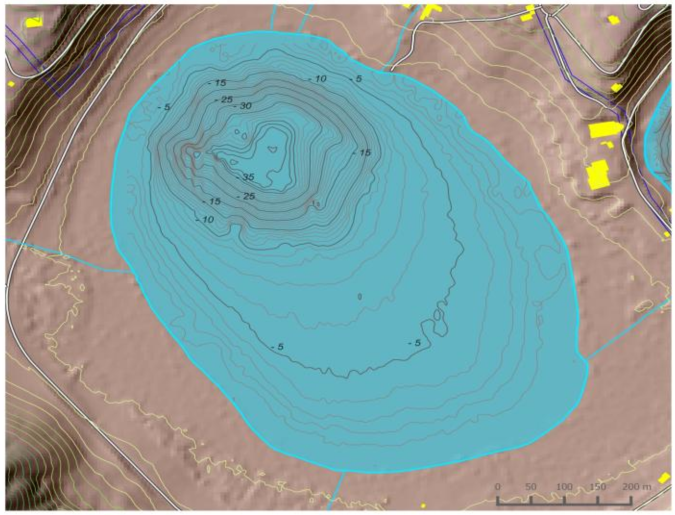

Figure 1. The bathymetry of LG carried out in 2015 (Spicciarelli & Miraudа 2015).

The pH profile decreases from surface to bottom, ranging from 9.1 to 5.9. This pH gradient exists because volcanic spring waters are rich in CO_2 and SO_2 that escapes from the residual volcanic activity. The photosynthesis of aquatic vegetation also contributes to the pH gradient [48, 49].

Habitats (Habitat Directive" 92/43/EEC)

3150 Natural euthrophic lakes are rich with *Magnopotamion* or *Hydrocharition*-type vegetation. The phytosociological investigations have led to the identification of 3 types of associations related to aquatic vegetation [50] 1) *Myriophyllo verticillati-Nupharetum lutei* Koch 1928; 2) *Potametum lucentis* Hueck 1931 and 3)*Ceratophylletum demersi* Hild 1956. The most frequent aquatic plants present in LG are *Ceratophyllum demersum*, *Myriophyllum spicatum* and *Nymphaea alba*.

Venanzoni *et al.* [50] have identified that the most frequent species in LG are: *Ceratophyllum demersum*, *Myriophyllum spicatum* and *Nymphaea alba*. The authors also identified the presence of the species: *Potamogeton lucens* L., *P. crispus* L., *Polygonum amphibium* L., *Myosotis scorpioides* L. However, the latter species were not found later [51, 52]. This is particularly important when considering that *P. lucens* is the species guide of Habitat 3150.

91E0* Alluvial forests with *Alnus glutinosa* (L.) Gaertn. and *Fraxinus excelsior* L. (*Alno-Padion, Alnion incanae, Salicion albae*). In Monticchio area, endemic animals and plants of high biogeographic interest are present such *Lutra lutra* L., *Alburnus albidus* (Costa), *Brahmaea europaea* Hartig and its food plant *Fraxinus angustifolia* subsp. *oxycarpa* (Willd.) [28, 29]. The trees are narrow-leaved with less widespread in Habitat 91E0*, Alluvial forests with *Alnus glutinosa* (L.) Gaertn. and *Fraxinus excelsior* L. (*Alno-Padion*, *Alnion incanae*, *Salicion albae*), which are comparable with *Taxodium distichum* (a plant that is very well adapted around LG) [53]. From 2011, this habitat remained submerged throughout the year due to the obstruction in drainage channel. A local condition that is leading to the death of numerous individuals of southern ash as of the alder (*Alnus glutinosa* (L.) Gaertn.). The habitat cannot expand to higher altitudes, because the circumlunar road physically impedes spontaneous expansion.

Plants

Nymphaea alba L. 1753 (fam. *Nymphaeaceae*) and European White Waterlily (EWW) are important aquatic perennial plants which are rooted on the muddy Lake bottom by means of a fleshy, slightly branched rhizome which produces healthy floating foliage along with gorgeous, scented, hermaphrodite, self-fertile flowers which blooms from June to early August in Italy. This area is rich due to alkaline water marshes [48] ponds, slow moving streams and lakes or canals [54]. The species spreads easily in purity in the *Myriophyllo verticillati – Nupharetum lutei* Koch 1928 phytocoenosis but it is found with other aquatic and macrophytic species ((*P. lucens*, *P. crispus*, *C. demersum*, *M. spicatum*).) in *Potametum lucentis* Hueck 1931 phytocoenosis [50].

EWW successfully competes with other aquatic plants for nutrients and light [55, 56, 57, 58], that resists to conditions of high acidity or alkalinity [59]. These species withstand temporary for lowering of the water level [11, 13, 26], but it can suffer negative effects from its elevation [25, 60, 27]. *Nymphaea alba* is considered invasive and when it is aided by eutrophication, it expands rapidly [58]. These species are included in IUCN Red List of threatened species classified as Least Concern as it is widespread with stable populations and does not face any major threats [61]. In LG, the specie populations cover high surfaces especially in the southern part of the lake, characterized with a lower seabed that slopes gently towards the central depression. In LP, *N. alba* is present with a small nucleus, already found by Trotter in 1905 [62].

Taxodium distichum (L.) Rich 1810, (fam. *Taxodiaceae*) and Bald Cypress (BC) were introduced in Europe in the 1637 through England by John Tradescants [63] and arrived in Italy during the XVIII century as ornamental tree. In the 30s of the XX century it was used for reforestation in marshlands and wetlands. At present, it is as casual non-native species in Lombardy and Veneto (northern Italy) [64]. These species are capable of living from seedling to maturity in soils waterlogged areas [19, 65, 24). In the study area, BC was planted in the reforestation carried along the banks of the lakes of Monticchio in the 50s of XX century. The presence of several specimen of *T. distichum* within *Carici remotae – Fraxinetum oxycarpae* phytocoenosis characteristic of Habitat 91E0* were already reported by Venanzoni et al. [50].

Materials and Methods

Ground survey, aerial photographs and satellite images were carried out during the period of April 2002 to December 2017 as listed in Table 2 and Table 3.

Table 2. Input data used for *Nymphaea alba* expansion assessment

Image	Source	Shooting date	Resolution (m)
2002	Google Earth Pro	September 16	<1
2006	Photo taken by drone (Geocart srl, Potenza - Italy)	July 26	0.02
2008	Agea	June 27	0.50
2011	Agea	July 15	0.50
2014	Google Earth Pro	July 4	<1
2015	Google Earth Pro	May 29	<1

In order to evaluate the inter-annual fluctuations of EWW, six aerial photographs were taken during the summer due to highest expansion rates. The collected data is described in Table 2 compared across time and space which consists of aerial photos of different sources, also by drone equipped with a high-resolution Infrared camera, as adopted by Boret & Reeber [66]. In particular, airborne photos of Agenzia per le Erogazioni in Agricoltura (AGEA) and images of the Google Earth Pro platform were used.

Google Earth Engine is a well-known free Internet application that provides a large library of satellite images and aerial photos with global coverage. The data are provided at high resolution (<1 m) and the platform provides low cost and technologically easy analysis tools for territorial analysis [67]. Google Earth Pro provides a combination of the visible bands useful to recognize spatial patterns through visual interpretations. This platform is efficient to identify and select complex spatial information in a more accurate way than any other device or algorithm [68, 69, 70, 71, 72 ,73, 74].

We required high resolution photographs and digitized the expansion areas of *N. alba*. These photographs were georeferenced in the Reference System UTM WGS 84-33N. The expansion area of *N. alba* was measured over several years by comparing it with bathymetry [47]. A focus was made on the forms of 3 EWW pads on the lake by comparing the different shots.

For the identification of the current cypress expansion we acquired remotely sensed images and executed field surveys. In particular, images of the Sentinel-2 were selected in the autumn-winter period (year 2017) as shown in Table 3 in such a way to have greater discrimination between the radiometric response of Taxodium and that of the surrounding arboreal vegetation.

Table 3. Satellite data input for actual *Taxodium distichum* expansion assessment

Mission	*Tile*	*Shooting date*	*Resolution of visible and NIR bands (m)*
Copernicus	S2A_MSIL1C_20170329T095021_N0204_R079_T33TWF_20170329T095024	29-Mar-17	10
Copernicus	S2A_MSIL1C_20171015T095031_N0205_R079_T33TWF_20171015T095357	15-Oct-17	10
Copernicus	S2A_MSIL1C_20171224T095421_N0206_R079_T33TWF_20171224T122256	24-Dec-17	10
Data used for K-means clustering classification			
Satellite	*Bands and Vegetation Indices*	*Date*	*Central Wavelength*
Sentinel-2	Band 2	March, October, December 2017	Blue (490 nm)
Sentinel-2	Band 3	March, October, December 2017	Green (560 nm)
Sentinel-2	Band 4	March, October, December 2017	Red (665 nm)
Sentinel-2	Band 8	March, October, December 2017	NIR(842 nm)
Sentinel-2	NDVI	March, October, December 2017	-
Sentinel-2	EVI	March, October, December 2017	-

The images were georeferenced in the WGS84-33N UTM which were subjected to pre-processing steps. The whole tiles were treated for the clouds masking using the Idepix algorithm (Identification of Pixels), a pixel identification tool, available as a SNAP plugin. This tool needs a Sentinel-2 L1C product for masking. Subsequently, atmospheric correction was performed using the Sen2Cor algorithm, present in the SNAP application of the ESA (European Space Agency), suitably developed for treatment of images by Copernicus mission. Sen2Cor is built upon scene classification and look-up tables from a radiance transfer model such as MODTRAN. Finally, the Sentinel-2 tiles were cropped for the area of interest (Figure 2).

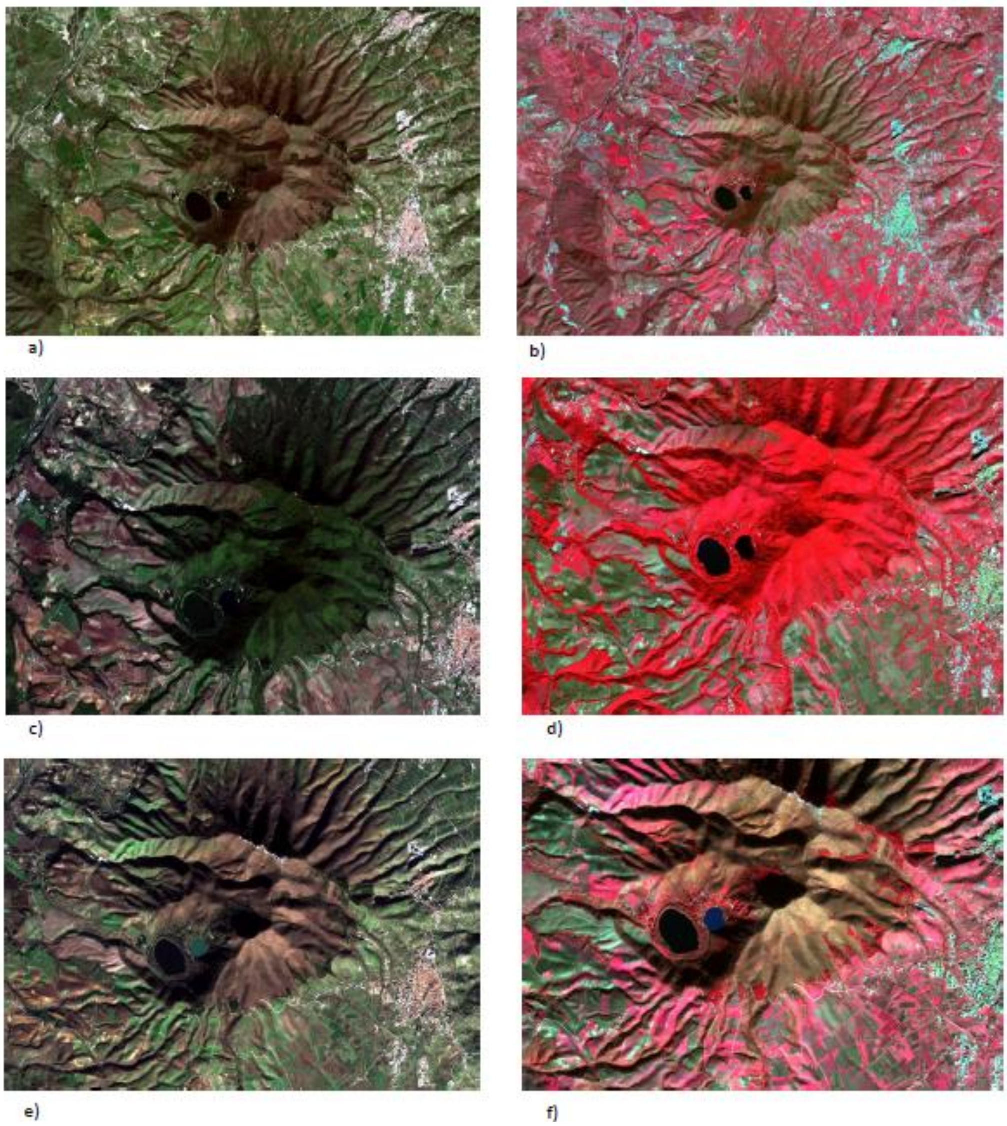

Figure 2. Sentinel-2 images of 29 March 2017 in true colour composition (a) and false infrared colour (b); of 15 October 2017 in true colour composition (c) and false infrared colour (d); of 24 December 2017 in true colour composition (e) and false infrared colour (f) of the current distribution of *Taxodium distichum*.

We processed the Sentinel-2 images that would allow greater differentiation with respect to the surrounding deciduous vegetation during the months March, October and December. Well renowned vegetation indexes e.g., Normalized Difference Vegetation Index (NDVI) as formulated in Equation 1 and the Enhanced Vegetation Index (EVI) as formulated in Equation 2 were computed as below,

$$NDVI = \frac{(NIR - red)}{NIR + red} \qquad \text{Equation 1}$$

$$EVI = \frac{2.5 * (NIR - red)}{(NIR + 6 * red - 7.5 * blue + 1)} \qquad \text{Equation 2}$$

While NDVI [75] is capable to identify the chlorophyll content [76, 77, 78] and the amount of biomass [79, 80]. EVI [81] is more sensitive to the structural characteristics of vegetation [82, 83, 84] and to the phenology [85, 86, 87]. Therefore, both the vegetation indices provided better understanding of availability of biomass e.g., *Taxodium distichum*. We proceeded to an automatic classification using the K-means clustering algorithm [88] by computing NDVI and EVI indices using visible and the near infrared (band2, band3, band4 and band8) of Sentinel-2.

K-means clustering technique uses Euclidean distance for calculating the distances between pixels and cluster centroids and is a heuristic, greedy algorithm for minimizing Sum of Squared Errors (SSE).

The objective function is described in Equation 3

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2 \qquad \text{(Equation 3)}$$

Where $||xi(j) – cj||^2$ is a chosen distance measured between a data point $xi^{(j)}$ and the cluster centre c_j that is an indicator of the distance of the n data points from their respective cluster centres.

To check the precise distribution of Bald Cypress, we conducted field surveys, supported by the field map. The coordinate points after every 50 m where chosen to represent the cypress expansion limits. Subsequently with GPS survey in the field, the limit of expansion of *T. distichum* was traced with precision.

For the historical data on Bald Cypress, information was collected by interviewing operators and foresters and by sifting historical documents for data that could allow us to identify the period of transplantation. A flow chart of methodology adopted in this research is show in Figure 3.

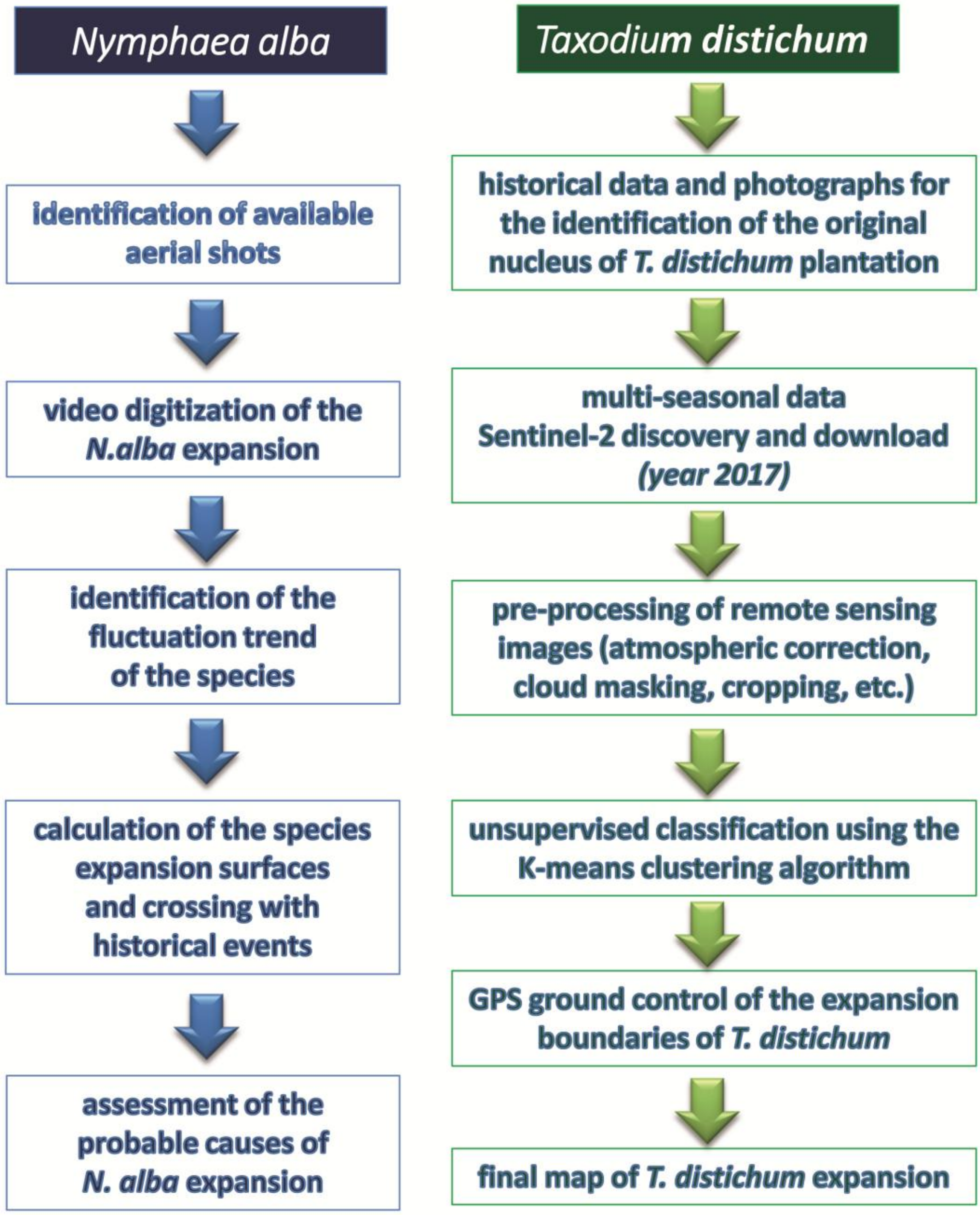

Figure 3. Flow chart of methodology adopted for *Nymphaea alba* (to the left) and *Taxodium distichum* (to the right).

Results and discussion

***Nymphaea alba* L.**

All aerial and satellite photographs available (from 2002 to 2015) were taken for the months May-September as shown in Figure 4,

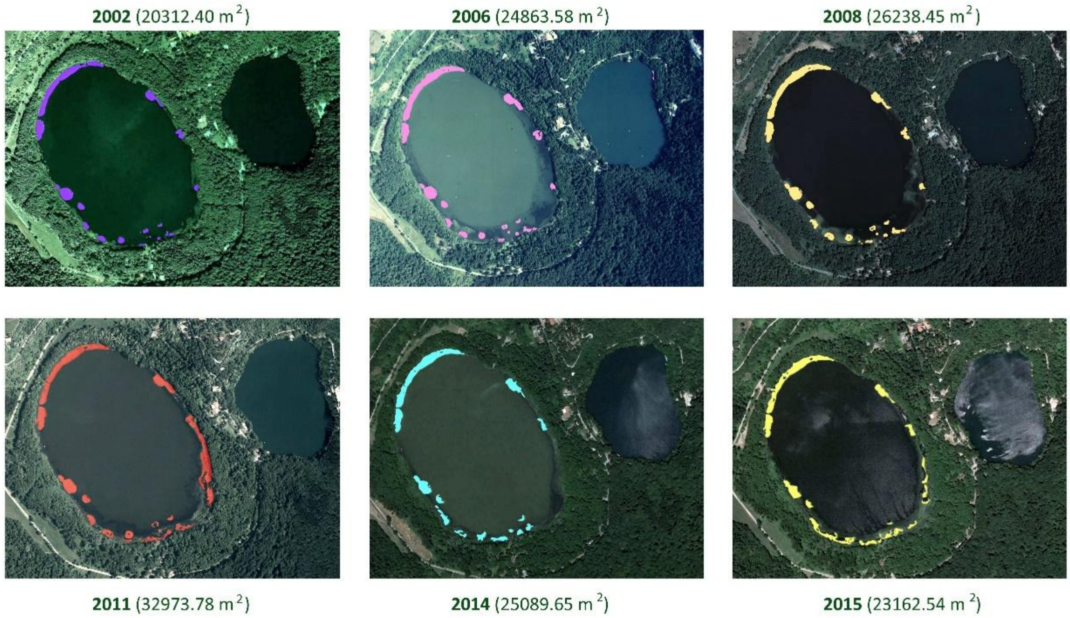

Figure 4. Areas occupied by European White Waterlily on the Lago Grande of Monticchio indicated with different colours for each year.

The area highlighted of *N. alba* populations, created for each image clearly describes the trend of the expansion of the laminate over the years as represented in Figure 5.

In this Figure 5, *N. alba* has increased its expansion on the surface of the lake with an expansion by 30%. Between 2011 and 2014, on the other hand, there was a decline of around 24% to laminate area. The spread of EWW on LG decreased again for the period (2014-2015).

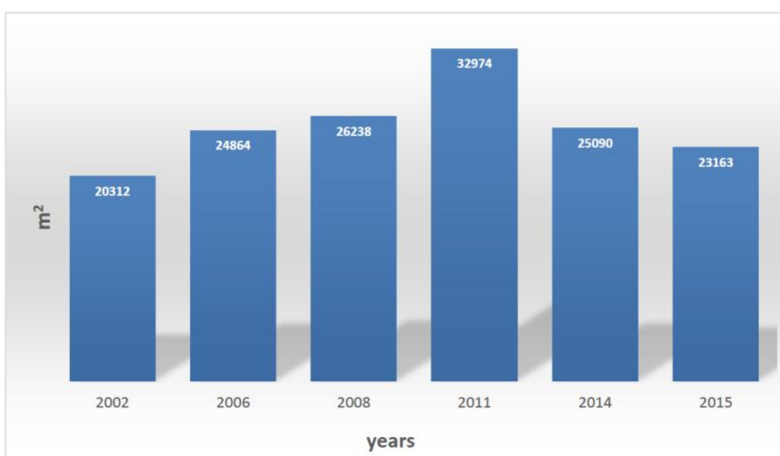

Figure 5. Surface occupied by European White Waterlily between 2002 and 2015.

Despite the evident recent decrease in the area occupied by the laminate, EWW is the main macrophyte of LG. *N. alba* occupies 6% of the surface of the lake, over 30% if we consider the surface of the lake with a depth lower than that of closing hydrophytic vegetation. By the overlapping the orthophotograph of 2015 with the bathymetric map of the same year, it is clear that 90% of EWW emerges from a depth of not more than 2 meters but is also found in cores at depths closer to 4 meters as shown in Figure 6,

Figure 6. The two lines indicate the bank and the isobath -5 m. European White Waterlily to northwest is very close to that line (2015).

By the observation of the Arial photographs of different years, we observed that EWW nuclei seem to first form themselves in a dense and compact leaflet then begin to "peel" from the inside, then fray and that disappeared in the 10-15 years as shown in Figure 7,

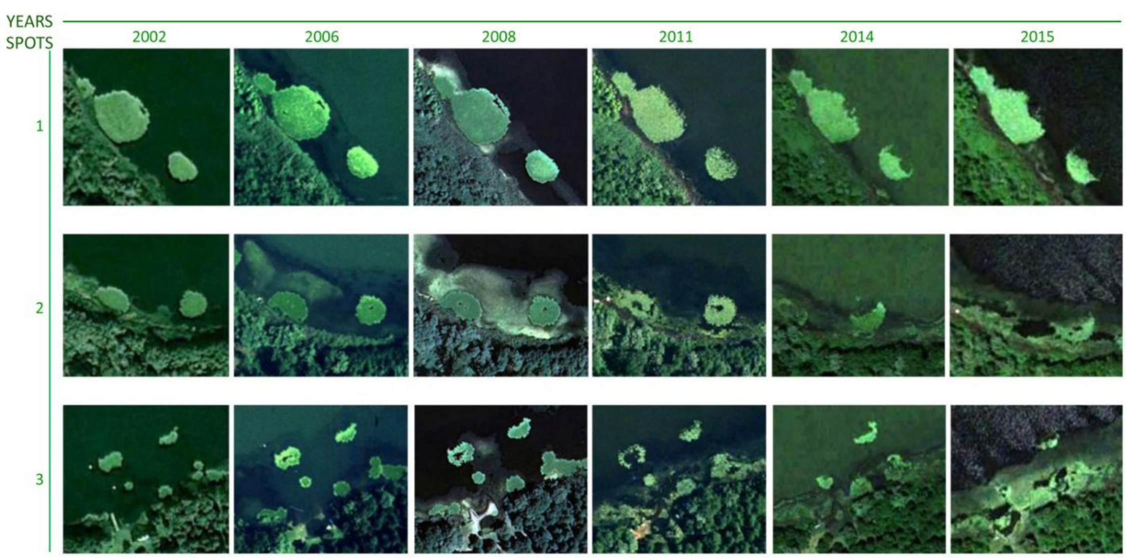

Figure 7. Three areas of the lake with EWW pads which describes spatio-temporal variations in evolution of feature from 2002-2015.

Another observation detected during the inspections which was the lifting and floating of rhizomes on the surface. A phenomenon circumscribed to specific sectors of the lake in areas less protected by the wind. The suspended material seems to constitute "small floating islands", which last from one year to the next with other plant species settle. On this, a hypothesis may be established that the hypogea part, anchoring to the seabed might be stimulated by the effect of strong wind on the floating part which have been particularly lengthened due to the water level [25] that produces a tear effect as shown in Figure 8

Probably, the particular diffusion of *N. alba* has consequences on the presence and on the diffusion of the other hydrophytes that characterize the submerged habitat of this lake. As in the cases of *Potamogeton lucens* L., *Potamogeton crispus* L., *Polygonum amphibium* L., *Myosotis scorpioides* L., species detected by Venanzoni et al. (work carried out from 1999 to 2000) were not found in 2010 by Azzella [51].

Figure 8. Rhizomes of European White Waterlily rising from the bottom of Lago Grande (September 2015).

The decline might be due to two events that took place between 2011 and 2012 1) the obstruction of the emissary with the raising of the water level [25] and 2) the particularly low temperatures during the winter of 2011-2012, which have frozen the waters of LG for a few days. The decreasing of the surface occupied by EWW is very limited following the lifting of the rhizomes in some small area of the lake. Subsequent measurements on the expansion of the species are necessary to understand, if the reduction recorded in recent years, will continue and if at the same time the other aquatic macrophytes will regain a greater living space.

The species can be particularly intrusive. It is necessary to foresee the possibility of reducing its extension by removing the causes and by reducing the effect of the causes that contribute to the eutrophication of the waters of Lago Grande di Monticchio [71]. At the limit, it is also possible to foresee a partial removal of water lilies, not so much to reduce the biomass present in water, also because their contribution is very limited [72, 73] to favour the development of other hydrophytes that are particularly significant for the habitat.

Taxodium distichum **(L.) Rich**

The testimonies, gathered by the elderly operators who directly carried out the planting of *T. distichum* around LG, allowed to date the first presence of this species in Monticchio Lakes. Simultaneously with poplars and alders, present along the banks, were planted several times starting from 1952 and to 1955 (before National Mountain Festival of 1956) as shown in Figure 9, In 1960, the cypresses appeared and the propagation material was purchased, while the poplars and the alder were produced in the plant nursery called "Solagna Lago Piccolo", along with other species (*Robinia pseudoacacia*, *Juglans regia*, *Ailanthus altissima*, *Pinus nigra*), details that emerge by Forest Management Plan of Monticchio Forest 1955-1964 [74].

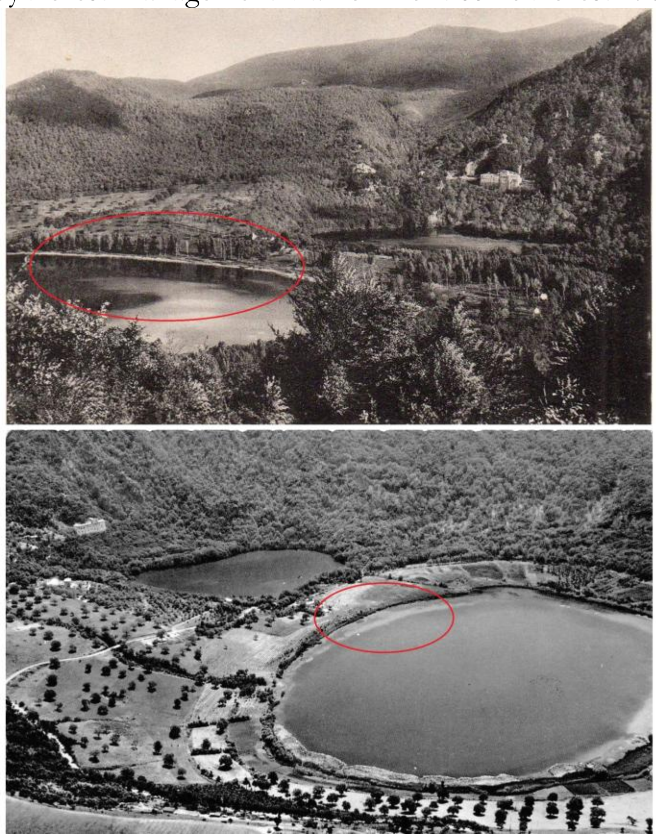

Figure 9. Two views of Monticchio Lakes: anterior to 1949 (over) and of 1958 (under). The new planting of Bald Cypress was circled in the latter, while the same space was visibly circled in the former, occupied by other plants.

For *Taxodium distichum,* the classification technique was used which provides satisfactory results. This technique has been widely used by various researchers [89, 90, 91, 92, 93] for various sensors and also for Sentinel-2 [94]. The classification results were efficient to identify the *Taxodium distichum* dislocation as shown in Figure 10. Finally, the surveys carried out in the field via GPS have made it possible to refine the boundaries of identified species.

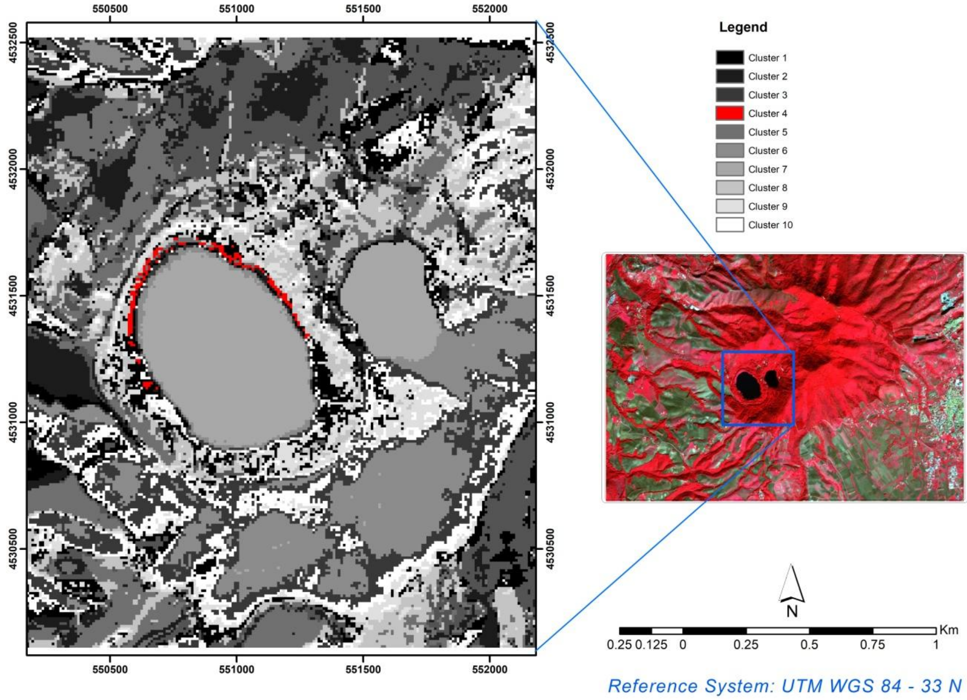

Figure 10. K-means clustering classification of Sentinel-2 images (in red the *Taxodium distichum* dislocation).

The integration of data obtained by different methodologies have allowed to realize a detailed map of *T. distichum* as shown in Figure 11. The multi-temporal comparison has highlighted its recent expansion along the emissary of Ofanto river that represents an important ecological corridor for fauna.

Figure 11. Spread of Bald Cypress along the shore.

In 2017, cypress grew along the shores of Lago Grande up to 925 meters linearly (about 38.8% of the perimeter of lake surface) and expanded over an area of 8,047 square meters, alder trees (transplanted a few meters from the shore, in rows having a distance of 5-6 meters between plants). On the site, the reproduction was exclusively agamic and the vegetational stage is demonstrated by the high production of galbuli, pneumatophores and the response of foliage infrared.

The evolution of *Taxodium distichum* reveals that the species spreads into Habitat 91E0*, with per consequences on the population of moth *B. europaea* having narrow-leaved ash is host plants. Certainly, the recent and accidental increase in lake level, with the submersion of many riparian surfaces, has favoured BC. Moreover, the hydrophytes (of low depth) near the cypress tree are absent or compromised by competition.

Despite being a non-native plant, currently it is a part of the landscape of Monticchio Lakes. This does not exclude the possibility of a decline to contain the population of *Taxodium* along the shore, in particular where it is inserted in the attic and at the end where it tends to expand along the shore.

The abnormal level of Lago Grande, which must be brought back to its historical levels as soon as possible, is causing profound changes into Habitat 91E0*, both in terms of reduction of the surface and in composition of its vegetation. In addition, the presence of hundreds of large specimens of alder and ash fallen into water or ground has been observed. The restoration of the main function of the emissary, that is to keep the lake level stable within certain limits, is particularly important, since the riparian habitat could not expand into higher areas due to the presence of the circumlacual road which constitutes an insurmountable physical obstacle.

Conclusions

The working methodology is based on combination of different informative source which revealed that some dynamics occurred during the last years in wetlands and riparian habitat of Lago Grande of Monticchio that resulted in expansion from 2002 to the 2011 and a decline was observed after this time. In accordance with the reports by other authors [25, 26], this trend is due to abnormal rising of the lake level up to 1 meter.

Currently, *Nymphaea alba* is dominant plant both on landscape and on other aquatic plants of the Lago Grande of Monticchio. In 2015, 90% of Lago Grande *N. alba* population emerged from a depth of no more 2 meters and 10% emerged from 2 to 4 meters.

The population of other aquatic plants (*Potamogeton lucens*, *P. crispus*, *Polygonum amphibium*, *Myosotis scorpioides*), and characterised species of the Habitat 3150 (Natural euthrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation) has been reduced which need to be monitored.

In recent years, on the lake shore, *T. distichum* continued to expand. In 2015, it occupied 38,8% the lake perimeter, with the surface decrement of Habitat 91E0* (Alluvial forests with *Alnus glutinosa* (L.) Gaertn. and *Fraxinus excelsior* L. (*Alno-Padion*, *Alnion incanae*, *Salicion albae*)). The Bald Cypress, was favoured by the abnormal level of the lake. The restoration of the main function of the emissary and a careful check of lake level are particularly necessaries to avoid profound environmental changes.

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