Aquatic Plants Invasion

GLOBE		Associated SDGs	Type of Activity
Spheres	**Associated Protocols**		
Hydrosphere	Water Temperature, pH, Dissolved Oxygen, Eléctrical Conductivity, Nitrates, Transparency and Macroinvertebrates	6 (Clean water and Sanitation) 13 (Climate Action) 14 (Life Below Water) 15 (Life on Land)	Exploratory
Atmosphere	Air Temperature, Surface Temperature, Precipitation		
Biosphere	Land Cover		
Bundle	Rivers and Lakes		

Overview

Series of satellite images of more than 20 years are compared to observe changes in water hyacinth cover in reservoirs in tropical areas. A case is analyzed with satellite images processed in false color to make measurements of areas covered by water hyacinth. Students analyze local impacts and possible uses of water hyacinth and explore ways of management

Time

3 or 4 classes

Prerequisites

Basic knowledge of ecosystems, food webs, populations, meteorology, water quality and ICT. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School Level

Upper Primary School, High School and University students

Purpose

To analyze the phenomenon of water hyacinth invasion in artificial reservoirs and its impacts in tropical areas

Student Outcomes

- To understand the impact of water hyacinth invasion in artificial reservoirs on human activities, health and the environment
- To analyze changes by observing image series since 2000

LEARNING ACTIVITY

- To interpret false color processed satellite images and conduct surface measurements from different years in Valsequillo Reservoir
- To explore variables that may influence the invasion of water hyacinth

Background

The water hyacinth or water lily (*Eichhornia crassipes*) is an aquatic plant that contains air chambers that allow it to float. Because of its purple and white flowers, it is used for ornamentation in parks, gardens, etc. It is a species native to the Amazon and de la Plata River basins. Many bodies of water in the world have been colonized by the water hyacinth for more than 50 years. The International Union for Conservation of Nature (IUCN) included it in the list of the 100 most invasive species in the world. This plant, under favorable conditions, reproduces very quickly and it is estimated that it can double its mass in 2 weeks (Watch video Invasive Species Corpoboyaca: Water hyacinth or A Dangerous Beauty, the Water Hyacinth.

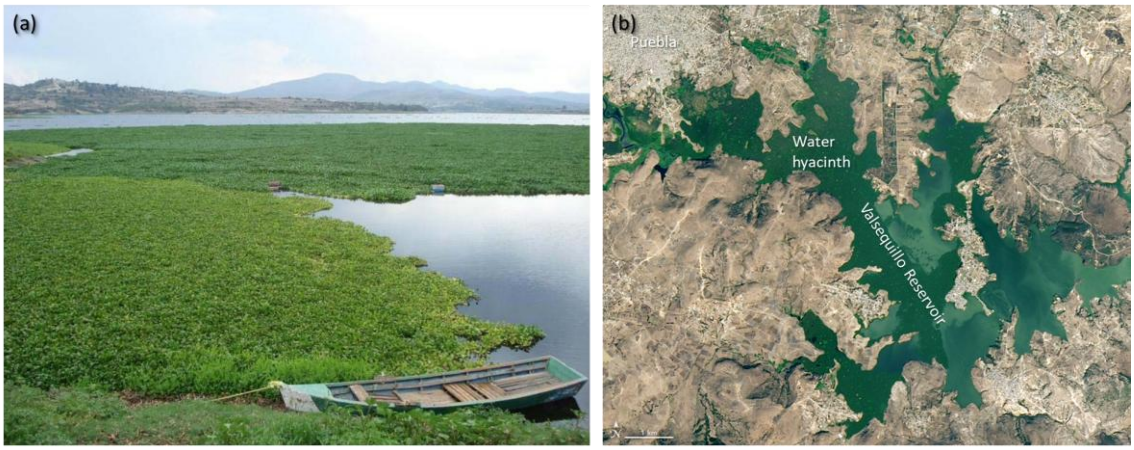

Fig. 1. Photo of water hyacinth in the Valsequillo Reservoir, Mexico (a). Landsat 8 satellite image taken on January 9, 2020 (b) showing the surface of the same reservoir covered by water hyacinths.

Scientific research has shown that water hyacinths have increased in reservoirs and lagoons in tropical areas in much of the world in recent decades, despite efforts to control them (e.g. Mexico, Colombia, Spain, several countries in Africa and Asia) (Watch video Invasive Alien Species - Aquatic Plants or Low Level Maintenance Control. This increase is associated with changes in land cover and inputs of pollutants to water bodies produced by runoff (from areas that were deforested, or crop fertilization, increased urbanization and sewage, etc.) that contribute phosphorus and nitrogen to the water. Water pollution with nutrients favors the growth of these plants, but water hyacinth can even grow in environments contaminated by heavy metals. They can retain cadmium, zinc, copper, manganese, mercury, chromium and arsenic. Among the main problems they cause are the obstruction of waterways, hydroelectric power plants, irrigation and drainage networks, etc. They also block the penetration of sunlight below the water surface producing a decrease in oxygen, altering the structure and function of the ecosystem, e.g. the reproduction of invertebrates and fish affecting the entire food web can also move towards a process of eutrophication. This generates socio-economic problems associated with aquaculture, fisheries, tourism, electricity production, water supply, etc. With their intricate branches and roots they trap plastics, retain them for a long time and transport them over long distances. In addition, water hyacinths provide

habitat for the development of disease vector organisms, for example, they facilitate the reproduction of mosquitoes causing the increase of diseases such as dengue fever, yellow fever, etc. that affect nearby communities. Because of these problems, different methods are used for their removal (mechanical, physical and biological).

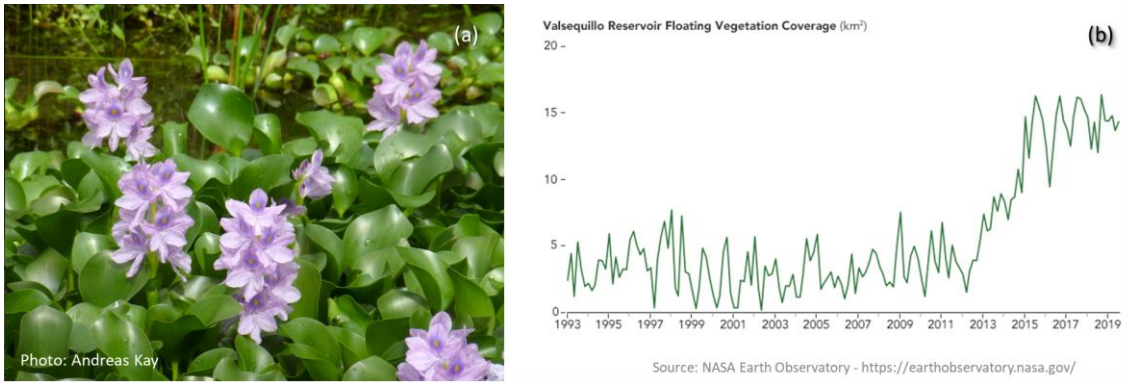

Fig. 2. Flowering water hyacinth (a). Changes in the cover of floating water hyacinth in the Valsequillo Reservoir, Mexico.

In addition to its ornamental use, the water hyacinth is also used as a bioremediatory to remove heavy metals and insecticides from contaminated environments. Extracted from the aquatic environment, it is used to produce ethanol, biogas, green manure (compost) and as food for some poultry (Watch the video Extraction and use of water hyacinth).

Studying water hyacinth invasions is important for designing control systems. Temperature variations cause changes in the density and extension of water hyacinth. It does not resist frost and prolonged cold temperatures below 5ºC and, when temperatures are above 37ºC, its growth is affected. Precipitation provides nutrients through runoff and helps the plants to spread in lakes and reservoirs. Currently, water hyacinths are widespread in tropical regions, but climate change could expand their distribution to latitudes that are now temperate and limit their growth. The rapid invasion of water hyacinths is generally associated with a pollution problem, even in their native range, in shallow and polluted waters. Water hyacinth coverage can be easily detected in satellite images. In Google Earth Engine it is possible to analyze time series of Landsat satellite images to detect changes.

Guiding Research Questions

- What was the historical range of water hyacinth distribution?
- What impact do water hyacinth invasions have on aquatic ecosystems?
- What are the characteristics of ecosystems that are invaded by water hyacinth?
- What are possible causes of the increased area covered by water hyacinths?
- How do water hyacinth densities vary throughout the year?
- What is the relationship among air temperature, water temperature, and precipitation to the area covered with water hyacinth?
- What types of land cover (urban, crop, industrial, etc.) exist around a reservoir or lake where water hyacinth invasion has occurred?
- What is the trend in year-on-year variation?
- Is water hyacinth invading water bodies near your location? What impacts did you detect?

Scientific Concepts

- Ecosystems

- Changes in the populations of some species
- Interrelationships of matter and energy in ecosystems
- Water quality. Eutrophication
- Environmental risks and vulnerability

Materials and Tools

Videos:

1. Comisión Federal de Electricidad (2022) *Extracción y aprovechamiento del lirio acuático*. YouTube https://youtu.be/JCOeLO4oCx8 [In Spanish]
2. Corpoboyacá (2021) *Especies Invasoras Corpoboyaca: Buchón de agua*. YouTube https://youtu.be/l2dcwVTpllw [In Spanish]
3. PNUD México (2020) *Especies exóticas invasoras - Plantas acuáticas*. YouTube https://youtu.be/xnBmof4c5Cw [In Spanish]
4. UF/IFAS (2021) *Low Level Maintenance Control.* YouTube https://youtu.be/XtjfdZtia5I
5. USACE (2020) *A dangerous beauty, the water hyacinth.* YouTube https://youtu.be/fV4A64TMz6k

Articles:

1. Harun, I., Pushiri, H., Amirul-Aiman, A. J., & Zulkeflee, Z. (2021). Invasive water hyacinth: ecology, impacts and prospects for the rural economy. *Plants*, *10*(8), 1613. https://www.mdpi.com/2223-7747/10/8/1613

2. Rodríguez-Lara, J. W., Cervantes-Ortiz, F., Arámbula-Villa, G., Mariscal-Amaro, L. A., Aguirre-Mancilla, C. L., & Andrio-Enríquez, E. (2022). Lirio acuático (Eichhornia crassipes): una revisión. *Agronomía Mesoamericana*, *33*(1). https://tinyurl.com/ys2mvf64 [In Spanish]

Google Earth Engine Timelapse: Compilation of satellite images from several years.

1. Valsequillo Reservoir, México. Changes observed from satellite.

2. Peñitas Reservoir, México (with aquaculture). Changes observed from satellite.

Satellite images processed in false color to highlight the state of the vegetation in the Valsequillo Reservoir:

1. *Valsequillo Reservoir* - Sentinel 2 Images - January: 2017 - 2018 – 2019 – 2020 - 2021 - 2022 - 2023 - 2024

2. *Peñitas Reservoir* - Sentinel 2 Images - January: 2017 - 2018 – 2019 – 2020 - 2021 - 2022 - 2023 - 2024

Note: The images are hosted on Copernicus Browser. To take measurements, you must create a free account. Check your language on the top left.

General Tools: Mentimeter (creates word cloud) - Cmap Cloud (to make concept maps)

What to Do and How to Do It

Beginning

1. Watch the videos "Invasive Species Corpoboyaca: Water buchon", "Invasive Alien Species - Aquatic Plants" and "Extraction and use of water lilies" or A Dangerous Beauty, the Water Hyacinth and Low Level Maintenance Control.

Development

1. Using the information from the videos and the introduction, brainstorm ideas and then create a word cloud or concept map.
2. Look at recent images of the Valsequillo and Peñitas. Reservoirs in Google Map. In the Peñitas Reservoir, observe the impact of water hyacinth on floating cages used for aquaculture.
3. Using Google Earth Engine Timelapse, ask your students to compare the changes observed from satellites at Valsequillo and Peñitas (you can change the images automatically or stop each year).
4. Divide the class into student groups to analyze the satellite images of the Valsequillo Reservoir.
    - Distribute 2 or 3 images to each group
    - Ask your students to use the ruler tool to delineate areas covered by water hyacinth.
5. Bring all the groups together and ask them to show the data obtained from each satellite image. Compare the area covered by water hyacinth in the different years and discuss considering the following questions:
    - Are there trends of increasing or decreasing area covered?
    - Which years stand out as having less water hyacinth cover? Which years have greater cover?
    - What variables might be influencing this (consider environmental variables and changes in land cover around the reservoir, changes in town size, etc.)?
    - Did any areas of the reservoir remain without water hyacinth cover? Did any regions remain unchanged? To what can this variation be attributed?

6. Ending

Complete the concept map above with the analyzed example and the comparison of satellite images from different years.

Frequently Asked Questions

How can I observe water hyacinth cover from satellite images? With Copernicus Browser and the false color combination highlighting the infrared band. You can also use other band combinations such as NDVI.

Where can I find false-color processed satellite imagery? In Copernicus Browser you can search for images from anywhere in the world.

What are the best dates to compare satellite images? The Landsat and Sentinel satellites pass over a certain site on some days, not all. For a better view of the Earth's surface,

you should choose images with few clouds and compare the same month in different years.

Tutorial Copernicus Browser

Suggested Resources for Further Information

As an extension of this activity, you can compare the images with temperature and precipitation data for the analyzed site, significant reduction events due to water hyacinth management (by manual, chemical, biological extraction methods).

To learn more about this phenomenon, we suggest reading one of the articles:

Harun, I., Pushiri, H., Amirul-Aiman, A. J., & Zulkeflee, Z. (2021). Invasive water hyacinth: ecology, impacts and prospects for the rural economy. *Plants*, *10*(8), 1613. https://www.mdpi.com/2223-7747/10/8/1613 [in English]

Rodríguez-Lara, J. W., Cervantes-Ortiz, F., Arámbula-Villa, G., Mariscal-Amaro, L. A., Aguirre-Mancilla, C. L., & Andrio-Enríquez, E. (2022). Lirio acuático (Eichhornia crassipes): una revisión. *Agronomía Mesoamericana*, *33*(1). https://dialnet.unirioja.es/descarga/articulo/8218098.pdf [In Spanish]

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Kriticos, D. J., & Brunel, S. (2016). Assessing and managing the current and future pest risk from water hyacinth, (Eichhornia crassipes), an invasive aquatic plant threatening the environment and water security. *PloS one*, *11*(8), e0120054. https://tinyurl.com/3xh2sxjj

Lowe S., Browne M., Boudjelas S., De Poorter M. (2000) *100 of the World's Worst Invasive Alien Species A selection from the Global Invasive Species Database.* The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), Auckland. https://tinyurl.com/rh82yk4p

Wright, C. (28 June 2022). Remote Sensing Tracks Down "Plastic Plants" in Rivers. Researchers are using remote sensing to track floating mats of plastic trapped in water hyacinth plants. *EOS. AGU*. https://tinyurl.com/4jsm85zf