MORPHOMETRIC CHARACTERISTICS OF TROPICAL SHALLOW RESERVOIR USED FOR AQUACULTURE AND AGRICULTURE IN THE MEXICAN PLATEAU

CARACTERÍSTICAS MORFOMÉTRICAS DE UN RESERVORIO SUPERFICIAL TROPICAL UTILIZADO PARA ACUACULTURA Y AGRICULTURA EN EL ATIPLANO MEXICANO

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Abstract

Morphometric characteristics of a tropical shallow reservoir situated in the Southern Mexican Highlands were studied. Seventeen morphometric parameters were measured. Results of the morphometric parameters showed that this reservoir presented a soft and roughness bottom, with an ellipsoid form and a concave depression that allow the mix up of water and sediments, causing turbidity and broken thermal gradients; its slight slopes allowed the colonization of submerged macrophyte and halophyte plants and they improve the incidence of sunlight on water surface increasing evaporation and primary productivity. Tropical shallow reservoirs have fluctuations in area and volume according to the amount of rainfall, the effect of evaporation, the temperature levels, lost of volume due to irrigation, and other causes.

Key words: Morphometry, bathymetry, tropical shallow reservoirs, Southern Mexican Highlands.

Resumen

Las características morfométricas de un embalse tropical localizado en el Altiplano Mexicano fueron estudiadas. Diecisiete parámetros morfométricos se determinaron en el cuerpo de agua. Los resultados mostraron que el reservorio presentó un fondo suave y rugoso, con una forma elipsoidal y una depresión cóncava que permiten la mezcla de agua y sedimentos, causando turbiedad y mezcla completa; su pendiente ligera permitió la colonización de plantas sumergidas, macrofitas y halófita y la incidencia de la luz solar sobre la superficie de evaporación de agua así como un aumento de la productividad primaria. Los reservorios tropicales someros tienen las fluctuaciones en el área y el volumen de acuerdo a la cantidad de lluvia, el efecto de la evaporación, la temperatura, la pérdida de volumen debida a la utilización del agua para el riego principalmente.

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Introduction

A limnological description of tropical shallow reservoirs is a necessary step in the research of the aquatic ecosystem (Hakanson, 1981). The morphology of shallow reservoir basin exerts a major control over a wide range of processes and features in a lacustrine ecosystem and reflects a series of actions closely related to its origin, operation and use. One of the oldest limnological principles is that basin morphometry influences lake metabolism (Thienemann, 1925; Neumann 1932), as a consequence, many studies have demonstrated how tropical shallow reservoirs morphometry affects the rate of certain limnological processes and the distribution of physical, chemical and biological parameters (Ponce-Palafox *et al*., 1998). In this sense Guiral & Pérez (1980) pointed out the importance of the cartography and morphometry of lake ecosystems as a first step in any kind of limnological research. In tropical shallow reservoirs of Latin America there are few studies on morphometric parameters. This research aim contributes to this type of knowledge by means of morphometric studies in tropical shallows reservoirs in the Southern Mexican Highlands.

Study area

The dry tropical shallow reservoirs are located in the geographic coordinates 18°39'40″N; 99°26'26.57″W in the extreme southwest of the State of Morelos, Mexico (Figure 1). They border north and west with the State of Mexico, south with the municipalities of
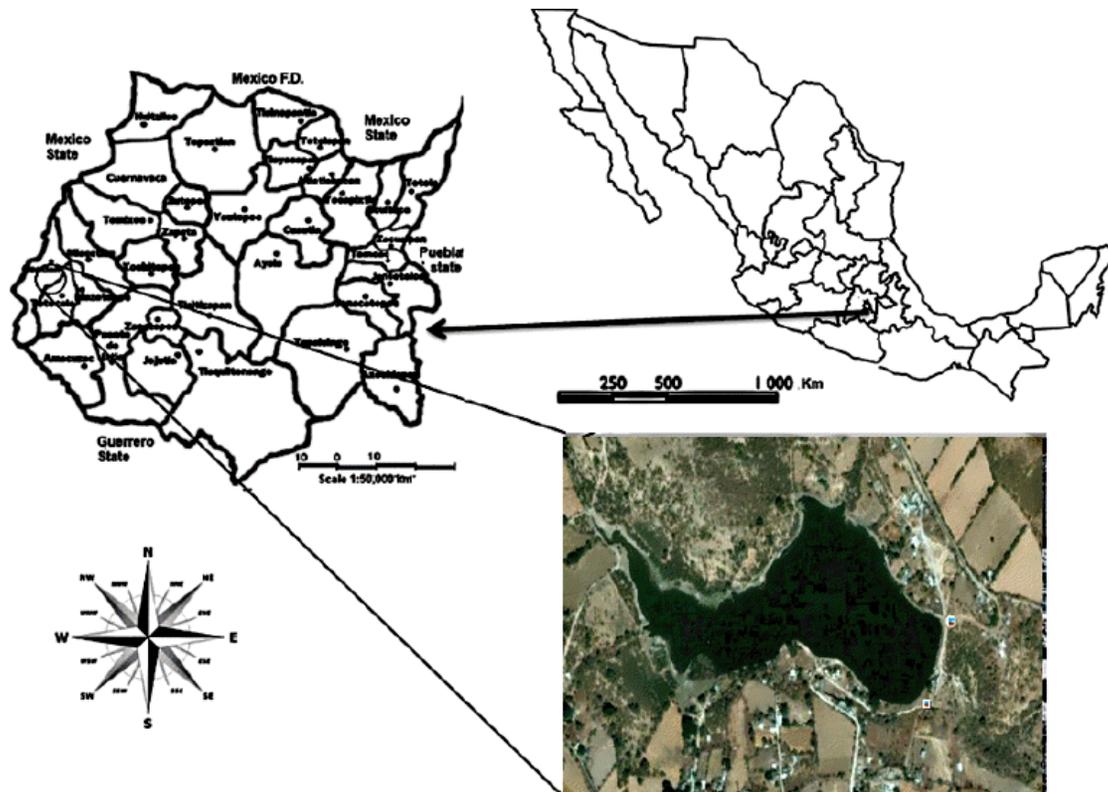

Figure 1. Geographic location of the tropical shallow reservoir "El Tilcuate", in the southern Mexican highlands.

Amacuzac and Tetecala, east with Tetecala and Miacatlán, and west with the State of Guerrero. The reservoir was studied, with a surface ranging from 86,636 to 128,000 m². This is semi-permanently, with an altitude from 1110 meters above sea level in a sedimentary soil area. The climate is warm, sub-humid with summer rains and a dry season in winter. The hottest months are April and May, while the coldest months are December and January. The average precipitation is 1000 millimeters per year. Maximum temperature is 34.0 °C, average 24.0 °C and minimum 14.0 °C. From a hydrological point of view, tropical shallow reservoirs receive direct supply from rainfall, groundwater flow, and surface runoff from sporadic streams.

Material and Methods

The construction of a bathymetric or contour map was performed during three different periods of the flood cycle, flooding during periods of minimum (March), medium (July) and maximum (September). The depth was determined at the deepest point near the gate of the reservoir, using a manual probe graduated in centimeters (Arredondo *et al*., 2007). The technique of separate segments was used in order to prepare the contour map, measuring the perimeter of coastline with a fiberglass 30 meter ADIR coated PVC tape measure graduated in centimeters and inches and resistant to extreme temperatures (Cole, 1994). To integrate

the superimposed line segments to the coast, we used a Directional compass Engineer orienting the segments according to the degrees of the four main directions (azimuth). Once in the laboratory, was performed the outline with the stroke of oriented segments in cumulative sequence completing the circuit, using the scale 1:400. Contour intervals were 0.5 m. The morphometric features of the shallow reservoir were determined according to Cole (1994), Coastal Line Development, Total Maximum Length (the longest axis of a water body), Effective Maximum Length, Perimeter, Area, Maximum Wide and predominant orientation of the TML were calculated by means of GIS operations and satellite image processing and the morphometric analysis followed Hakanson (1981).

Results and Discussion

The shallow reservoir is supplied with rain water and runoff from the mountains located at north; the upper basin is occupied by a zone induced grassland. The land has a gentle slope with north - south direction so that when it rains the water current drags sediments, which are deposited, in the shallow reservoirs. The watershed that drains into the reservoirs has an elongated shape with northwest - southeast orientation, with one single basin. This water body has fluctuations in area 86,636 to 128,000 m² (Figure 2) and volume, according to the amount of rainfall, the effect of evaporation, lost volume by
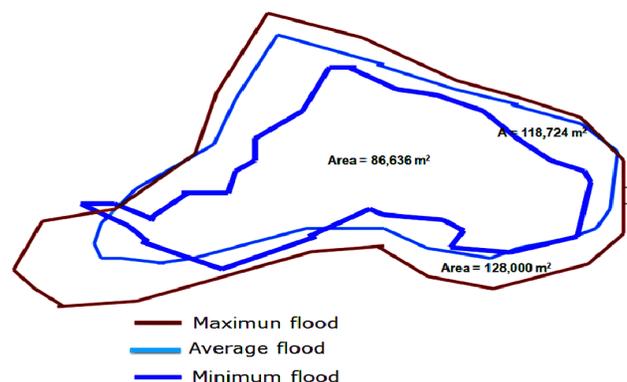

Figure 2. **Bathymetric contour map of the reservoir the "Tilcuate".** **Showing minimum, average and maximum flood.**

irrigation, and other causes. Leakage is caused by loss of sediment to provoke the so-called lateral loans (Naselli-Flores, 2003).

Their capacity fluctuated from 86,636 to 128,000 m^2 with an average of 118,724 m^2, they are shallow with a maximum depth from 4.3 to 9.7 meters. The morphometrical parameters of the tropical shallow reservoirs are shown in Table 1. Among these parameters, the mean depth (Z_{mean}) is probably the most important morphometric feature because it could be related with the productivity and trophic status (Hakanson, 1981). The shallow reservoir presented an average Z_{mean} of 5.42, indicating that their bottom is soft, easily removed and mixed with the water column causing turbidity. They serve as a surrogate for most morphometric attributes and a host of biological processes, but no correlation could provide with unambiguous information on underlying causes (Kalff, 2002). However, a low value of Z_{mean} normally tends to show high levels of nutrients in water and consequently is a productivity indicator (Sakamoto, 1966).

Moreover, mean depth may be used to determine the lake bottom roughness, which is a useful parameter in sedimentological studies and in the optimization models for lake hydrographical surveys (Hakanson, 1981). Neumann (1959) concluded that the depth ratio ($Z_{mean}\ Z_{max}^{-1}$) provides a useful approximation to lake form. The shallow reservoir showed an average value of 0.56, similar to an ellipsoid form that it is characteristic of shallow lakes with flat bottoms (Carpenter, 1983), and a relative depth (Dr) of 2.40 m. These values are related with the stability of the column of water and the stratification process that is typical of small and shallow basins.

Shore development was near of one and it represents a measure of the irregularity of the shoreline (Hakanson, 1981), which is one of the morphological parameters that reflects processes related to the lakes' origin. Dynamic ratio (DR) is designed to represent bottom dynamic conditions (Lindström *et al.*, 1999). The influence of this parameter over the diminishing

Table 1.
Morphometric parameters of the tropical shallow reservoir in the south-west of the State of Morelos: El Tilcuate.

Parameters	Amount
Area (m^2)	128,000
Volume (m^3)	694,095
Mean depth (m)	5.42
Maximum depth (m)	9.70
Relative depth (m)	2.40
Shoreline length (m)	2820
Shore development	2.22
Maximum length (m)	720
Maximum width (m)	350
Mean width (m)	177.8
Maximum depth (m)	9.70
Depth ratio ($Z_{mean}\ Z_{max}^{-1}$)	0.56
Volume development	1.68
Vd 3^{-1} (%)	56.0
1-Vd 3^{-1} (%)	44.0
Dynamic ratio	0.66
Direction of major axis	Southwest

of volume and other processes related to the water-sediment interface denoted its importance. The average dynamic ratio value of 0.66 indicates that there are lower bottom areas exposed to wind/wave energy. The developments of volume values were greater than one, which indicates a concave depression. The distribution coefficient (Vd 3^{-1}) is a useful tool to know the amount of sediment available for re-suspension on the erosion and transport areas (ET-areas), the fraction that goes to deep waters, and the fraction $(1-V_d \, 3^{-1})$ that goes to surface waters (Hakanson *et al.*, 2000). The values obtained mean that 49.0 % of the matter available is transported to deep waters and 51.0 % to surface waters.

The relative depth was above 2 %, which indicates the structure of daytime thermal discontinuities, however, in this case the water column is mixed by the effect of wind velocity over the fetch (707.95 m), resulting in a complete mixing, as a consequence the thermal gradient is eliminated. Shallow reservoir has slight shore slopes, although there is some dissimilarity between the two shorelines. The slight slope allows for colonization of the sediment by submerged macrophytes and halophytes (Ortega & Guerrero, 2003).

The slope of the reservoir was low. This improves the incidence of sunlight on the water surface, which increases the process of evaporation, therefore, heat loss, and gain in the water column increases primary productivity. The maximum length increases wind action creating movements that impact the entire mass of water throughout the day. This causes a greater exchange of material from the sediment (Barbanti, 1985). A perfectly circular basin has a shore development of one; irregular basins have values greater than one. It is important to know shore development as a starting input of nutrients to the reservoir as a function of the perimeter. Theoretically similar lakes in all morphometric traits, with the highest shore development will be more productive (Castro *et al.*, 2003). The Tilcuate has the highest development of the coastline with 2.22 than the other reservoirs that are in the same watershed.

Conclusions

Tropical shallow reservoir has fluctuations in area, and volume mainly due the amount of rainfall. Leakage is caused by loss of sediment so-called lateral loans. Shallow reservoir showed a mean depth ratio $(Z_{mean} \, Z_{max}^{-1})$ of 0.56 similar to an ellipsoid form that is characteristic of shallow lakes with flat bottoms. The relative depth for shallow reservoir was above 2 %, which indicates the structure of daytime thermal discontinuities. The mean depth is the most important variable in this water body. According the temporal behavior was found that the water body area decreased by 32.3 % of the rainy season to the dry season, which conditioned the dynamics of morphometric parameters.

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