p-ISSN 2460-0768 e-ISSN 2597-6044 *GeoEco, Vol. 12, No 2. July 2026 Page. 926 - 934*
https://doi.org/10.20961/ge.v12i2.118341 https://jurnal.uns.ac.id/GeoEco/article/view/118341

# ECO-ACTION MODEL BASED ON ECOPEDAGOGY FOR SEDIMENTATION MITIGATION IN THE CENGKLIK RESERVOIR

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## ARTICLE INFO

**Article History**
Received : 04/05/2026
Revised : 30/06/2026
Accepted : 31/07/2026

**Citation:**
Rohsulina, P., Deristani, A., Rahman, M.K., Sunarhadi, M.A., and Aji, B.K.(2026) Eco-Action Model Based on Ecopedagogy for Sedimentation Mitigation in the Cengklik Reservoir. GeoEco. Vol. 12, No. 2.

## ABSTRACT

The Cengklik Reservoir, as a strategic water resource infrastructure, has experienced a continuous decline in storage capacity due to sedimentation caused by both biophysical processes and anthropogenic activities within the catchment area, particularly agricultural land use. This study aimed to analyze the spatial distribution of sedimentation and to develop an ecopedagogy-based Eco-Action model as a participatory strategy for sustainable sedimentation mitigation. A mixed-methods approach was employed by integrating GIS-based spatial analysis with qualitative participatory methods. Spatial analysis was conducted through manual digitization of high-resolution Google Earth imagery (2025) using ArcGIS, followed by spatial overlay and field verification. Social data were collected through in-depth interviews with 30 respondents from Sobokerto and Ngargrejo villages. The results showed that sedimentation was spatially concentrated in the southern and northern parts of the reservoir, where sediment accumulation was associated with agricultural land and runoff pathways from the surrounding catchment. Based on the integration of spatial analysis and community perspectives, an ecopedagogy-based Eco-Action model was developed consisting of four stages: identification of sedimentation hotspots, environmental awareness through ecopedagogy, community-based conservation actions (gotong royong), and participatory environmental monitoring. The proposed model provides a conceptual framework linking spatial information with community participation to support sustainable sedimentation management and may serve as a reference for similar reservoir catchments.

***Keywords:*** *ecopedagogy; eco-action; mitigation; participation; sedimentation*

## INTRODUCTION

The Cengklik Reservoir plays an important role in supporting irrigation, flood control, and the socio-economic activities of surrounding communities (Piróg et al., 2025). However, continuous sedimentation has

p-ISSN 2460-0768 e-ISSN 2597-6044
https://doi.org/10.20961/ge.v12i2.118341


significantly reduced reservoir storage capacity and threatens its long-term sustainability. Sedimentation is primarily driven by soil erosion associated with land-use change, unsustainable agricultural practices, and climate variability (Ali et al., 2020; Do et al., 2022; Nur et al., 2024). In the Cengklik Reservoir catchment, erosion is estimated at 18.82 tons $ha^{-1}$ $year^{-1}$, contributing approximately 73,432.57 tons (275,502.84 $m^3$) of sediment annually, indicating a serious need for sustainable mitigation.

Previous studies have predominantly emphasized technical and engineering approaches, such as sediment estimation, spatial mapping, and sediment control structures (Savitri et al., 2023). Although these approaches improve understanding of sediment dynamics, they are generally reactive and provide limited attention to the role of communities in reducing sediment production at its source (Djalal Tandjung & Handono Ramelan, 2012; Robles et al., 2026). Conversely, studies addressing community participation and environmental awareness remain largely descriptive and rarely integrate spatial sedimentation information with environmental education or explain how behavioural change can contribute to sedimentation mitigation (Ardoin et al., 2020; Debrah et al., 2021; Leal Filho et al., 2018).

Ecopedagogy offers a potential approach to bridge this gap by promoting environmental awareness that leads to collective conservation actions. Increased environmental understanding can encourage sustainable land management practices, reduce soil erosion, and ultimately decrease sediment delivery into reservoirs (Vente et al., 2018.).

The novelty of this study lies in integrating GIS-based sedimentation mapping, community perceptions obtained through in-depth interviews, and an ecopedagogy-based Eco-Action model within a single conceptual framework. Unlike previous studies that examined technical and social aspects separately, this research combines spatial and socio-educational approaches to support sustainable sedimentation management. This study aims to analyze the spatial distribution of sedimentation and to formulate an ecopedagogy-based eco-action model as a participatory and sustainable mitigation strategy.

p-ISSN 2460-0768 e-ISSN 2597-6044
https://doi.org/10.20961/ge.v12i2.118341


## MATERIALS AND METHODS

This study employs a mixed-methods approach that integrates spatial analysis with participatory qualitative methods to comprehensively examine sedimentation in the Cengklik Reservoir. This approach was selected to bridge biophysical evidence obtained through geospatial mapping and analysis with the social dynamics of local communities as key actors in environmental mitigation (Goodchild, 2018).

The research focuses on communities surrounding the reservoir, particularly in Sobokerto and Ngargrejo villages. Thus, the method is designed not only to identify spatial patterns and levels of sedimentation but also to understand community perceptions, behaviors, and participation potential in sustainable mitigation efforts.

1. Data Collection

Spatial and social data were collected to examine sedimentation conditions and community participation in the Cengklik Reservoir. Spatial data consisted of high-resolution Google Earth imagery (2025) and field observations. Field surveys were conducted to verify sedimentation areas and record supporting documentation (Goodchild, 2018).

Social data were obtained through in-depth interviews with 30 respondents selected using purposive sampling, comprising community members from Sobokerto and Ngargrejo villages with direct knowledge of sedimentation issues. The interviews explored community perceptions, environmental knowledge, conservation behaviour, and opportunities for participatory sedimentation mitigation (Vente et al., 2018).

2. Data Analysis

Sedimentation areas were mapped using ArcGIS through manual on-screen digitization based on high-resolution Google Earth imagery from 2025. ArcGIS was employed to delineate the spatial extent of visible sediment deposits and to visualize their distribution within the reservoir. The digitization results were verified through field observations to ensure agreement between the mapped sedimentation areas and actual site conditions. The results were validated through ground-checking to ensure consistency with field conditions (Foody, 2020).

The Eco-Action model was developed using an integrative mixed-methods approach by combining GIS-based

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spatial analysis and qualitative data from in-depth interviews. Spatial analysis was used to identify sedimentation hotspots, while thematic analysis of interview data explored community perceptions, environmental awareness, and conservation practices.

## RESULTS AND DISCUSSION

1. Spatial Distribution of Sedimentation

Based on **Figure 1**, the interpretation of Google Earth imagery and field verification, the total sedimentation area in the Cengklik Reservoir reached 52.3 ha. The spatial distribution of sediment was not uniform but was concentrated primarily in the northern and southern sections of the reservoir. These areas represent river inflow zones where runoff transports eroded soil particles from the surrounding catchment into the reservoir. In contrast, the eastern and southeastern parts remain relatively deeper, although early signs of sediment accumulation have begun to emerge along the littoral zone.

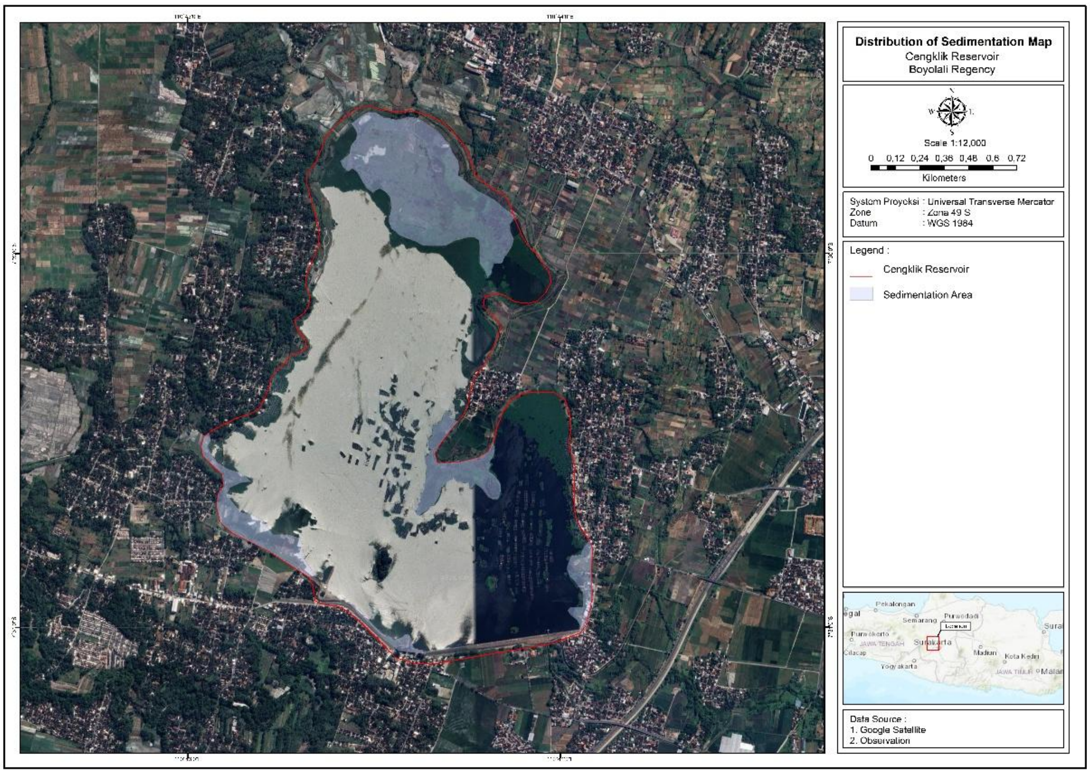


**Figure 1.** Distribution of Sedimentation
Source: Observation and processing data

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This sedimentation phenomenon is driven by a combination of natural processes and anthropogenic activities surrounding the reservoir. Intensive agricultural activities in the catchment area remain one of the primary contributors because cultivated land with limited vegetation cover is highly susceptible to erosion during rainfall events. Surface runoff subsequently transports sediment through rivers and drainage channels into the reservoir (Panagos et al., 2016).

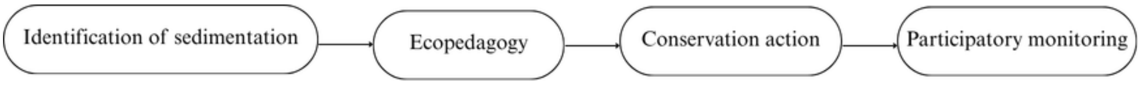


**Figure 2.** Model Eco-Action
Source: Data Analysis

Based on **Figure 2**, each stage represents a continuous process through which scientific information is translated into collective environmental action. Rather than proposing conservation activities without spatial prioritization, the model was designed by integrating GIS-based sedimentation mapping with community perspectives obtained through in-depth interviews. This integration enables mitigation strategies to be directed toward sedimentation hotspots while simultaneously strengthening environmental awareness and community participation.

2. Identification of Sedimentation

The first stage focuses on identifying sedimentation hotspots through GIS analysis, field verification, and local knowledge. Spatial mapping identified approximately 52.3 ha of sediment deposits concentrated around inflow areas and agricultural runoff pathways. This information enables stakeholders to prioritize conservation activities in areas with the highest sediment contribution rather than implementing generalized interventions throughout the reservoir. Spatial prioritization also supports more efficient allocation of environmental management resources and strengthens evidence-based decision making.

3. Ecopedagogy

Theoretically, this stage is grounded in the ecopedagogy paradigm, which emphasizes critical consciousness regarding human–environment relationships. Sedimentation is interpreted not merely as a geomorphological process but as a consequence of unsustainable land management within the catchment (Panagos et al., 2015). This educational process shifts communities from passive recipients of environmental information toward active agents capable of addressing the root causes of environmental degradation. Furthermore, integrating deep learning strengthens higher-order thinking skills by enabling communities to analyze environmental problems, evaluate alternative solutions, and develop context-based conservation initiatives (Darling-Hammond et al., 2020).

4. Conservation Action

Environmental awareness developed through ecopedagogy is translated into conservation actions implemented collaboratively by local stakeholders. These actions include community clean-up activities (gotong royong). Compared with structural approaches such as dredging or sediment control infrastructure, these eco-actions emphasize prevention by reducing sediment production at its source (Kondolf et al., 2014).

Community participation in upstream land conservation indirectly contributes to reducing erosion rates, which remain the principal source of reservoir sedimentation (Leal Filho et al., 2018). Consistent with previous studies, participatory conservation generates stronger ownership and enhances the long-term sustainability of environmental management because local communities become directly involved in planning and implementing conservation programs (Pretty & Bharucha, 2015).

5. Participatory Monitoring

The final stage consists of participatory environmental monitoring to evaluate the effectiveness and sustainability of conservation programs. Communities participate in observing sediment accumulation, vegetation development, and environmental conditions while communicating monitoring results to relevant stakeholders. This participatory monitoring mechanism promotes continuous evaluation and adaptive improvement of conservation activities.

However, the effectiveness of this model is influenced by several contextual factors. Teacher capacity in implementing project-based environmental learning, institutional support from schools and local governments, and socio-economic conditions surrounding the reservoir all affect participation levels and the sustainability of conservation initiatives. Moreover, although qualitative findings demonstrate improvements in environmental awareness and community participation, further integration with hydrological and geomorphological monitoring is required to quantitatively evaluate reductions in sedimentation over time (Arabameri et al., 2019).

## CONCLUSIONS

The proposed Eco-Action model extends previous studies by integrating spatial sedimentation mapping, ecopedagogy, conservation action, and participatory monitoring into a single framework. Unlike conventional sediment management approaches that primarily emphasize engineering interventions, this model combines environmental education with community participation to promote sustainable behavioral change. Consequently, the model provides both a conceptual contribution to geography and environmental education and a practical framework that can be replicated in other reservoir catchments experiencing similar sedimentation pressures

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