Tecnical Note

Hazards Caused by Uncontrolled Vegetation and Inadequate Maintenance Practice in Earth Dams

• Félix Escolano-Sánchez* •
Universidad Politécnica de Madrid, Spain
*Corresponding author

• Roberto Fernández-Serrano •
Centro de Estudios y Experimentación de Obras Públicas, Spain

Abstract

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Small dams for irrigation use are often managed by landowner communities. Dam owners are responsible for the routine maintenance actions of each dam and their common irrigation system net. Due to various social factors, like population ageing or farming loss, in areas where there has been a notable decline of agriculture, the maintenance activity of the irrigation hydraulic net is defectively conducted. An inadequate practice of maintenance first allows the growth of vegetation which may develop over the dam embankment surface, affecting to the compacted earth structure. Trees and big shrubs that grow on dam slopes and crest may have a negative impact on certain geotechnical aspects. Apart from vegetation, once that owners neglect their maintenance obligations, animal invasion or human wrong uses go with vegetation growth. The paper shows frequently found vegetation impacts observed in Spain, along with animal or human impacts, which may involve geotechnical problems. General conclusions and recommendations have been proposed in order to help owners to maintain their dams and to avoid long term problems.

Keywords: Small dams, vegetation, maintenance, negative impact.

Resumen

Escolano-Sánchez, F., & Fernández-Serrano, R. (noviembre-diciembre, 2015). Peligros causados por vegetación incontrolada y mantenimiento inadecuado en presas de tierra. Tecnología y Ciencias del Agua, *6(6), 137-144.*

Las presas pequeñas, cuyo uso se destina al riego, a menudo son gestionadas por las comunidades de propietarios, responsables de las labores de mantenimiento y de la red del sistema de riego que mana de ellas. Debido a diversos factores sociales —como el envejecimiento de la población en las zonas rurales, que implica merma de las áreas agrarias cultivadas— existen áreas donde la actividad de mantenimiento de la red hidráulica de riego se lleva a cabo de forma defectuosa. Una práctica inadecuada del mantenimiento favorece la colonización de la vegetación no controlada, lo que afecta la estructura de tierra compactada de diferentes maneras. Esta nota muestra de modo gráfico los impactos observados en España, con frecuencia por la vegetación, que en conjunto con la presencia de animales, puede implicar un riesgo. Se proponen conclusiones generales y recomendaciones, a fin de ayudar a los propietarios a mantener sus presas y evitar problemas a largo plazo.

***Palabras clave**: presas pequeñas, vegetación, mantenimiento, impacto negativo.*

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Introduction

The vegetation in small earthen dams is a problem in relation with a geotechnical point of view. The uncontrolled growth of vegetation can damage embankments and concrete structures and make regular inspection difficult. In general, the geotechnical effect of woody vegetation growth has been considered as common factor which aggravates the swelling and mainly the shrinkage

and subsidence problems of root-dried ground causing movements in foundation design (Biddle, 2001).

An example for small dams is given by Pfost and Curry (1996), considering the vegetative control benefits when controlling erosions or filling rills and gullies, by trying to maintain a vigorous vegetative growth.

When trees and woody plants are allowed to grow on earthen dams, they can hinder safety inspections, can interfere with safe operation, or can even cause dam failure (Committee on the Safety of Existing Dams, 1983; FEMA, 2005). Actually, more precise investigation should be carried out by survey of root-study methods (Böhm, 1979), in order to have an idea of how deep or inside the embankment it has penetrated.

Vegetation is not the only problem associated to the lack of maintenance operation. Proper maintenance of embankment dams require that burrowing animals be prevented from burrowing on the dam and that they be eradicated if they are present on a dam embankment (López-Jimeno, 1999).

Uncontrolled Vegetation Growth

Trees and brush should not be permitted on embankment surfaces or in clay or rip-rap conformed spillways. Extensive root systems can provide seepage paths for water.

There are a number of physical weathering processes that break earth materials apart; a very common one is called root wedging, when plant roots work their way into rock mass joints. As they grow, roots create pressure on the sides of the crack enlarging it until the rock breaks apart. This common phenomenon causing slope instability in rock ground by opening cracks and fissures, increasing gradually in size in a manner similar to the action of the wedges.

Woody Vegetation on Dam Crest and Upper Upstream Slope

It has been observed that when trees and brush grow on upstream slope they show up by alignments, in general 1-2 m over the saturation line in a regular Full-Supply (reservoir) Level. This behaviour is a matter of fact when the reservoir presents high water level almost all the year (Fig. 1 and Fig. 2).

The most dangerous aspect of tree growth on dam crests and upper upstream slopes is their sudden uprooting. This can result in the displacement of a relatively large amount of embankment material, thereby lowering the dam crest, reducing the effective width of the dam, or facilitating erosion and potential seepage.

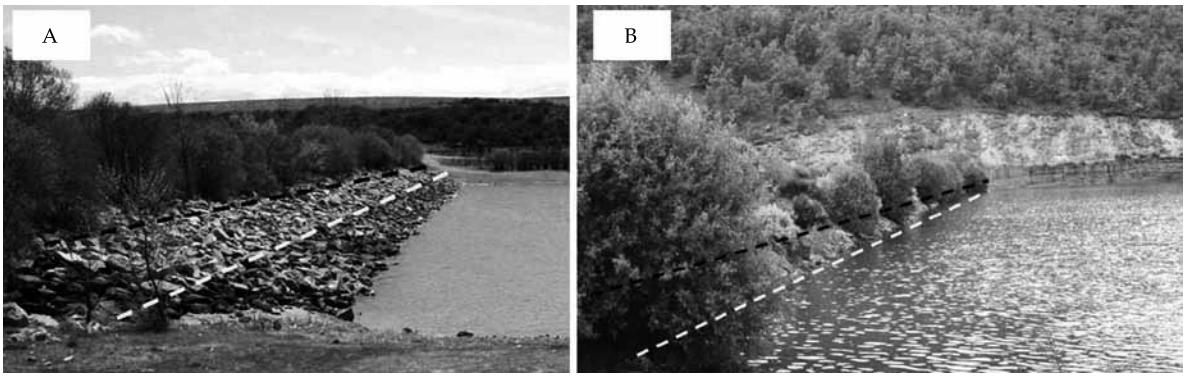

Figure 1. Upstream view of a rockfill dam with clay core. (A): White line is Normal Level. Black line is trees alignment (Villagatón Dam, Spain). (B): White line is Full Supply Level. Black line is trees and brushes alignment (Santa Lucía de la Sierra Dam, Spain).

Figure 2. Trees behind a reinforced concrete wall, which is an abutment of the spillway channel bridge. (Santa Lucía de la Sierra Dam. Spain).

Woody Vegetation Affection on Rigid Structural Elements and Drainage Net Channels

Trees growing in wall backfills or close to water channel fabric and other dam structures are able to push walls, uplift channel foundations and become an obstacle on the free flow of water (Fig. 3). Actually, it could be difficult for vegetation to grow enough to break concrete structures, but the real problem in relation with maintenance is important in two different ways:

Maintenance labours and planned dam inspections are significantly affected or disabled in the worst case. In some cases the concentration of trees and woody vegetation on an embankment is so dense that a visual evaluation of the dam cannot be performed.

Vegetation invades drainage elements reducing the free water flow cross section. In other case, roots uplift the channel reducing or reversing the angle of descent, forming puddles (Fig. 4). The potential problem has to do with the eventual overflow of water.

Spillways are the most important safety elements on dams, so they must be always clean of brushes and tree trunks which can prevent the correct water flow in normal or emergency dam-work situations (floods). Trees growing on the reservoir near the spillway lip are water obstacles (Fig. 5), and potential clogging bases. For the case depicted in Fig. 6 of a tree that has grown just in the middle of spillway, in the upper side of the downstream slope, should have also been removed to prevent potential problems of seepage, erosion, burrowing animals, etc.

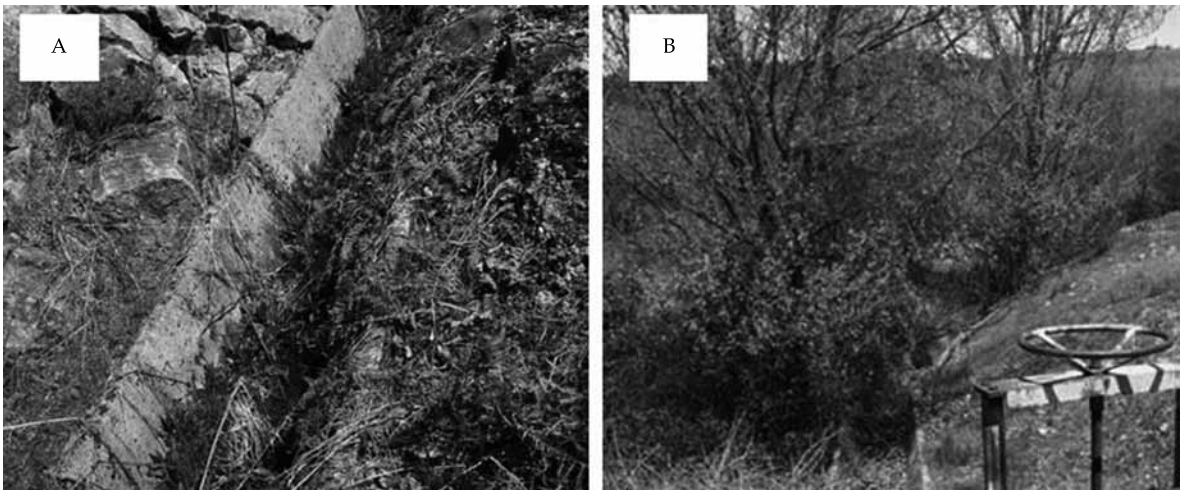

Figure 3. A: Drainage net element of a downstream berm reducing cross-section of water flow. B: Trees rooted behind a service surplus channel downstream of an earth dam.

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Figure 4. Small trees growing close the static crest spillway of a small dam.

Figure 5. Big tree growing just below the dam crest in the spillway channel of an earth dam, under the spillway dam crest bridge. The channel continues with a rip-rap cover along the downstream slope.

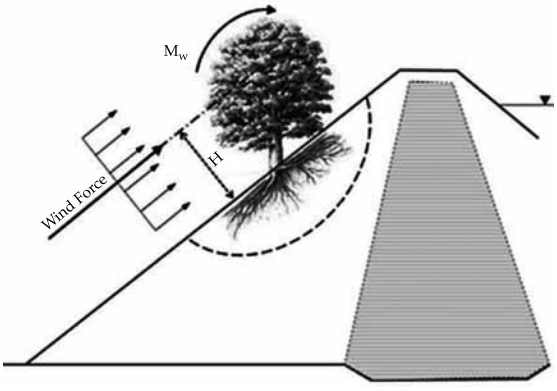

Figure 6. Wind-induced moment MW acting on well-rooted tree transferred into adjacent portion of slope. (After Coppin and Richards, 1990).

Woody Vegetation in the Downstream Slope

Many dam owners plant woody vegetation on their downstream slope dams to provide pleasing landscape effects. When it is possible, for the case of an upstream concrete face rockfill dams, downstream slope can be revegetated by using geocells in order to integrate the dam in beautiful landscapes.

For the case of earth dams, trees and brush rely on an extensive root system to provide oxygen, nutrients, and moisture as they grow. In general, the root ball is located below the trunk, and the lateral root system spread outward from the trunk to the "drip line" of the plant's canopy. The large root ball and extensive roots of trees and brush easily penetrate earthen dams; while the roots stabilize the plant, they destabilize the dam.

Another limitation is the overloading by weight and wind. The wind force exerted on the plant is transferred into the ground unbalancing the system of forces and inducing instability. In this way, it may cause rotation and tilt of trees, particularly if they are exposed to strong winds (Fig. 7).

Typical Riparian Zone Vegetation

Riparian woody species generally have shallow root systems, maybe with shallow lateral roots or deep sinker or taproots. Depending on the local conditions and vegetation existing around the dam, other species, not considered as riparian, can grow over an earth dam, like oaks or pines, producing deeper root systems.

In any case, trees and brush rely on an extensive root system to provide oxygen, nutrients, and moisture as they grow. The roots penetrate the embankment according to the groundwater conditions, usually without entering the saturated compacted soil, remaining above the water table.

Vegetation Associated Burrowing Animals

Rodents burrows on the upstream and downstream slopes can dramatically alter how a dam controls the water pooled behind the dam. Many species excavate dens and burrows within embankment dams, causing large voids that weaken the structural integrity of the dam.

Figure 7. European snow vole ("Chionomys nivalis"), typical on the north of Spain, living inside an earth dam. (Horno Tejero Dam, Spain).

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2007 vole outbreaks in NW Spain is an example of how pest control was necessary in order to protect crops. Apart from the agricultural implications, voles were detected in small dams (Fig. 8).

Surface Erosion

Gully Erosion and Overtopping

Inadequate spillway output maintenance can develop back erosion if channel covering has not been well designed. This is a minor problem since it can be solved by (e.g.) extending a rip-rap bed. The real problem is uncontrolled overtopping. The case of Ontígola Dam (Spain), a dam constructed by 1552, covered by vegetation, is an example of surface erosion related to vegetation growth (Fig. 9), while brush prevent from observing the uncontrolled overtopping as the most hydraulic dangerous behaviour of the dam.

Geotechnical Impact of Vegetation on Dams Discussions

It is difficult to establish a list of geotechnical impacts of vegetation on earth dams because there is not enough recorded experience and no clear dam collapse have been detected directly caused by vegetation. Some ideas about vegetation growth have been put in order in relation with the geotechnical hazards of small earth dams (Gilbert & Miller, 1991).

Hazards

Trees and brush represent a geotechnical potential hazard when they grow and their roots easily penetrate earthen dams. A number of dams have been observed to remain still in service to a residual irrigation area showing possibility of abandonment. The adverse effects can be resumed:

- Internal erosion (piping) induced by the decaying roots of dying woody vegetation that creates a seepage path can be presented when the vegetation dies and the decaying root system can provide paths for seepage and cause piping to occur.
- Roots can penetrate existing cracks and joints in the foundation soil/rock
- Overturning and uprooted trees cause holes on the dam. Large trees could be blown over and uprooted during a storm. Uprooted

Figure 8. Surface erosion caused by overtopping of a 1552 construction year wall-dam (Ontígola Dam. Spain).

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trees displace a large amount of soil and the resulting hole left by the root system (rootball) could breach the dam or shorten the seepage path and initiate piping.
- Spillways capacity could be reduced when falling trees mixed with brush get stuck into the water flow cross-section. Vegetation in the dam spillway or discharge channels reduces their hydraulic rate flow and their working and drainage capacity.
- Clogging drainage systems.
- Opening cracks in foundation or abutment joints between dam and natural ground.
- Woody vegetation shades the embankment and reduce dense grass coverage, which can be useful to prevent gully erosion.

Hazards Prevention and Solutions

In operating dams it is a requirement to inspect and assess the problems with trees and shrubs that grow over these dams. Shrubs and trees should be removed and its growth prevented in the body of the dam. Burrowing animals can cause seepage through a dam, which may lead to dam failure.

Vegetation Treatment for Surface Erosion Protection

Surface runoff erosion is one of the most common maintenance problems of embankment structures. If it is expected that surface erosion or rainfall form gullies on the downstream slope some dam owners determine the planting of some type of vegetative cover (usually grass) on the slopes to provide erosion protection currently available (e.g. geomembranes, geocells-cellular confinements systems, etc.). In this case a careful maintenance of the plants may be considered and planned.

US FEMA (2005) consider that the grass cover should be maintained to a maximum height of approximately 10-15 cm to allow proper embankment inspection.

Woody Vegetation Affecting the Dam

The best situation for a geotechnical dam inspection is always the "naked" slope. This helps situation for monitoring and maintenance, identification of dam patches, caused by eventual seepage, cracking, sinkholes, slumping, settlement deflection, and other signs of pathology.

Although a surface protection is desirable in arid or semi-arid regions, where gullies can be formed by strong rainfall, the growth of free vegetation may cause undesirable deep-rooted vegetation, such as large shrubs and trees, when maintenance is a secondary fact, which is a main problem herein.

The best approach to trees in the crest, slopes, and adjacent to the dam is to cut them down before they reach significant size. It is not recommended to use herbicidal deliveries when treating the upstream face because it must be avoid the contaminant contact with reservoir.

Animal Damage Associated with Vegetation

Burrowing animals should be avoided from dams because they make nests and passageways. These passageways may cause internal erosion failures if they connect the reservoir to the downstream slope or shorten seepage pathways through the dam.

Wildlife mitigation measures typically include habitat modification, trapping, fumigants, toxicants, frightening, repellants, or shooting, used singularly or in combination. However, applied indiscriminately, mitigation methods can adversely affect the dam environment, protected wildlife species, and even human populations.

Conclusions

The public administration should plan programmed inspections in order to check that a good maintenance activity is being carried out by the owners. Routine dam inspection and management along with dam owner information campaigns are the basic prevention rules.

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All types of woody, deep-rooted vegetation and brush growing on dam embankments or in the spillway are considered a problem and should be controlled. Taking early action to remove vegetation before it becomes established is a critical part of dam maintenance.

Not only dam body but hydraulic elements should be controlled. The operation of the spillway is critical to dam safety along with the rest of discharge channels and drainage system net, which should be considered as parts of the dam.

Woody vegetation root penetration represent a performance of earthen dams hazards. It does not stabilize a soil mass and creates a condition more conducive to surface water penetration and slope failure, apart from surface erosion protection that should be controlled.

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Authors' institutional address

PhD. Félix Escolano Sánchez

Department of Civil Engineering: Construction Technology
Polytechnic University of Madrid (UPM)
C/Alfonso XII, 3 y 5
28014 Madrid, Spain
Phone: +34 913364201
Fax: +34 913367750
e-mail: felix.escolano@upm.es

PhD. Roberto Fernández-Serrano

Centre of Studies and Experimentation of Public Works (CEDEX)
28014 Madrid, Spain
C/Alfonso XII, 3 y 5
28014 Madrid, Spain
Phone: +34 (91) 3357 324
Fax: +34 (91) 3357 322
roberto.fernandez@cedex.es

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