Reliability Analysis of the Influence of Vegetation on Levee Stability

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Overview

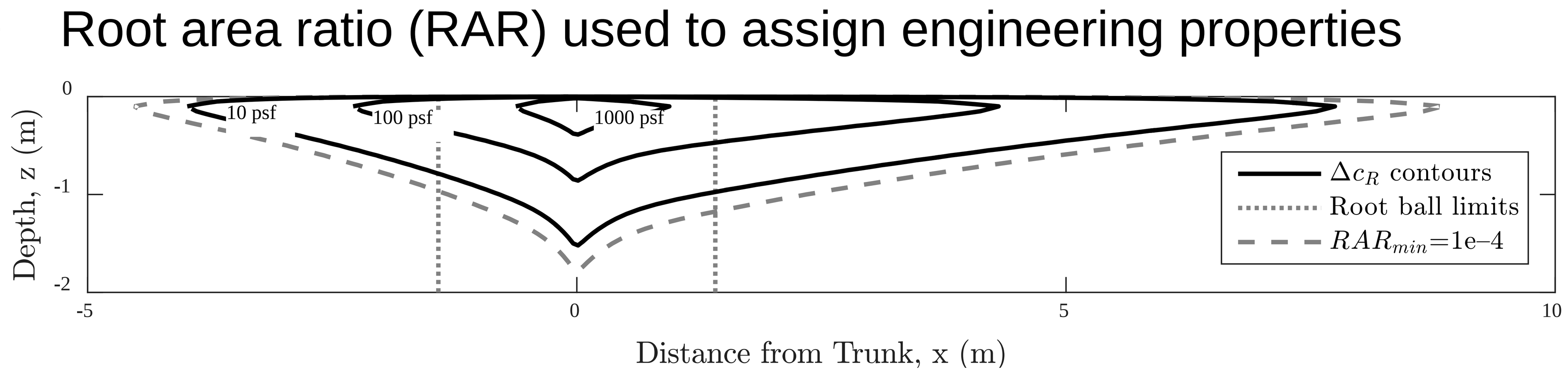
Quantification of woody vegetation effects is needed to address the changing regulatory environment for levee management agencies. Trees and their root systems have historically been considered a threat to levee integrity, but are typically not considered in design since large uncertainty exists with respect to root diameter and spatial distribution. However, recent studies by the California Levee Vegetation Research Program have provided new information. The objective of this project is to quantify the incremental effect of vegetation on levee performance due to the influence of tree size, location, weight and root density using seepage, stability and reliability analysis.

Analytical Tools

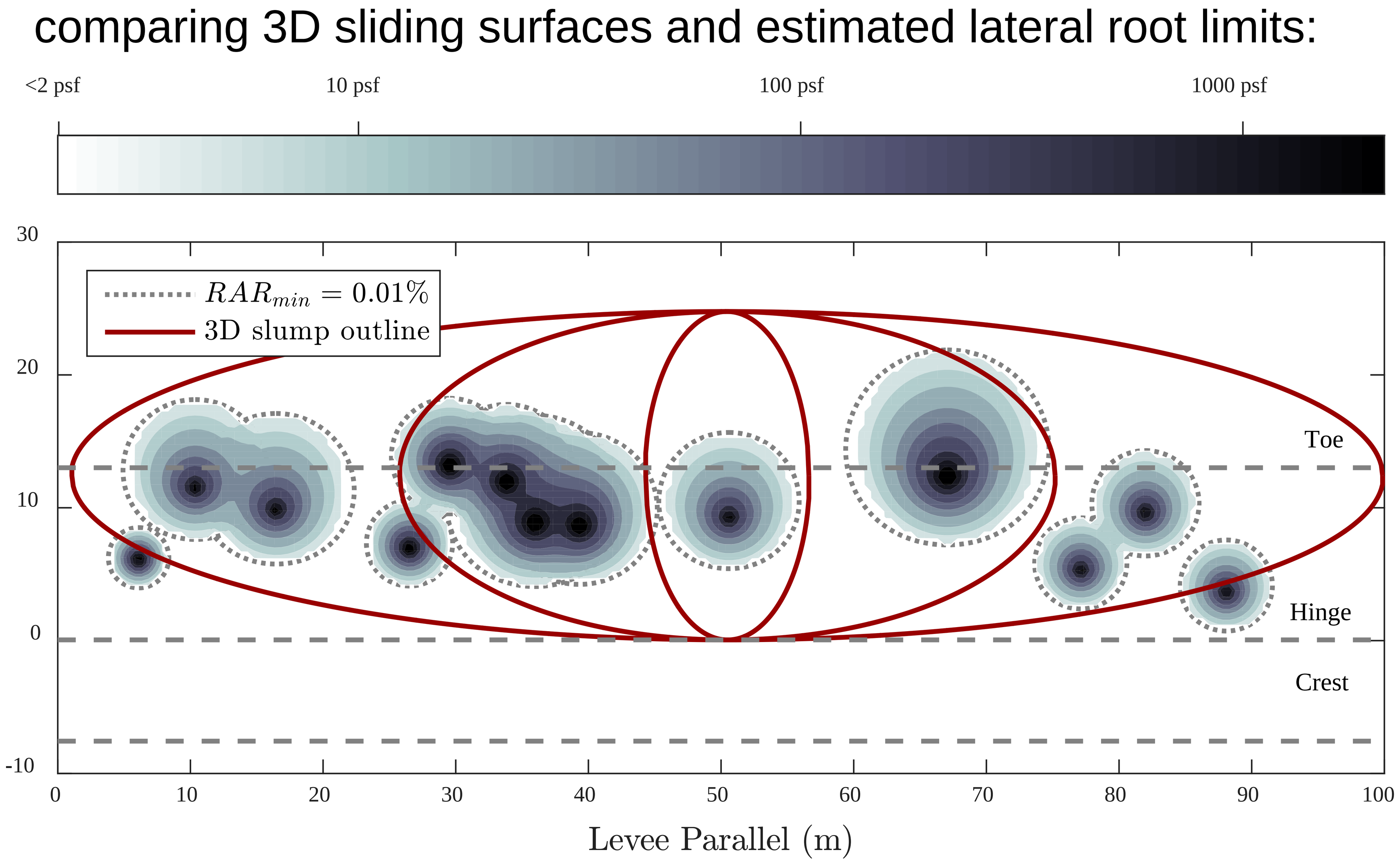
- Seepage: saturated/unsaturated finite element method
- Stability: Spencer's Method, with novel non-circular surface search
- Reliability: first-order reliability method (FORM) with FERUM
- All components integrated and evaluated with Matlab
- Model levee based on the Pocket area of Sacramento

Biomass Model

- Based on 3D LiDAR scans of excavated root systems
- Correlated to diameter (DBH) and averaged in 2D across root zone
- Root area ratio (RAR) used to assign engineering properties



Root reinforcement (effective cohesion) for a surveyed levee slope, comparing 3D sliding surfaces and estimated lateral root limits:

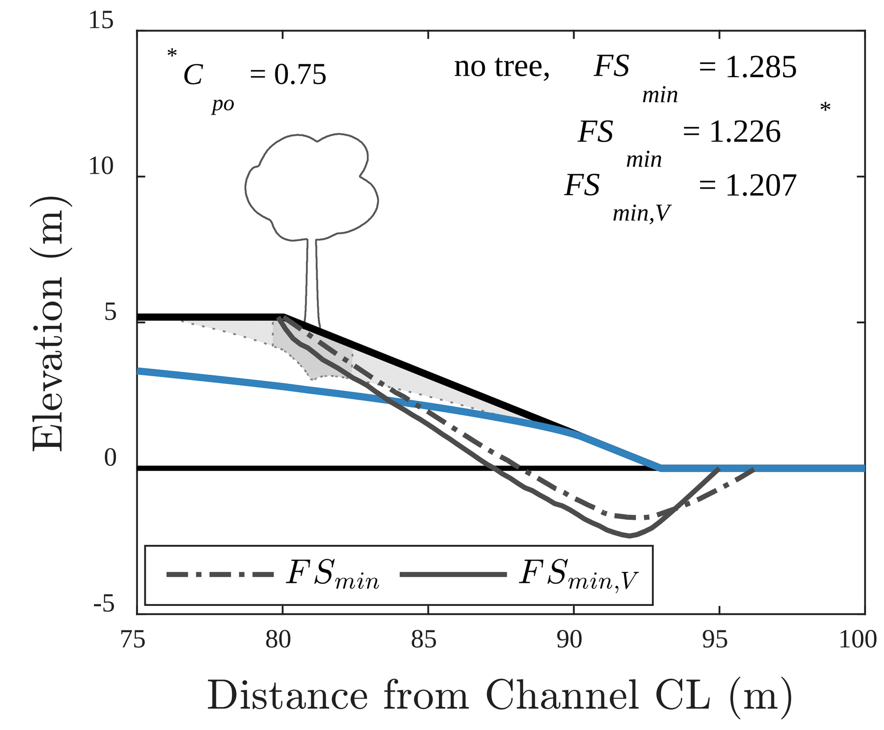


Conclusions

- Vegetation effects on *FS* are generally <10% (stability and seepage)
- Root reinforcement increases stability, but cannot be relied on given the 3D geometry of potential sliding surface
- Uncertainty in levee response due to non-vegetation parameters is much greater than uncertainty introduced by vegetation

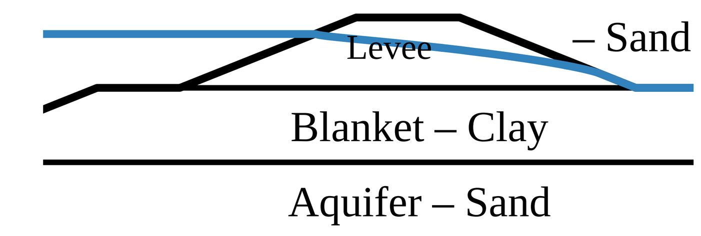
Slope Stability

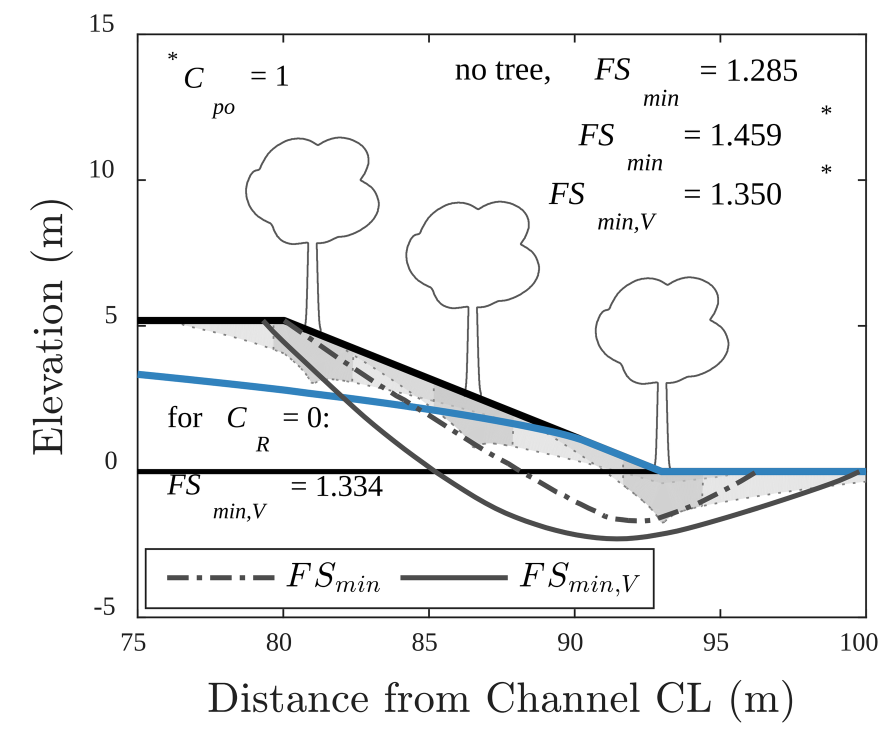
Trees are incorporated via root reinforcement, weight and wind, which produces a quantifiable ΔFS and changes the critical sliding surface.



Non-circular searches for new critical surface.

Adding a 1 m diameter tree to the original surface decreases *FS* from 1.3 to 1.2, but a new surface can be found with slightly lower *FS*





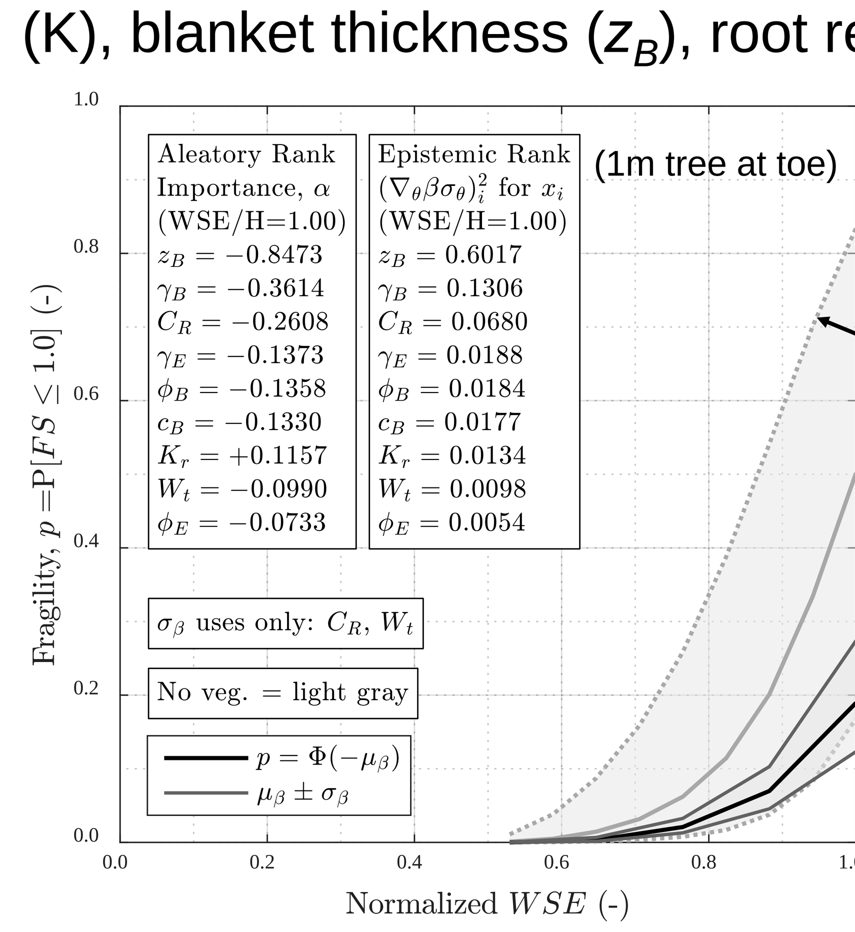
Adding three 1 m diameter trees to the original surface increases *FS* from 1.3 to 1.5, but a new surface can be found with *FS* = 1.4.

With weight only (no roots) new surface has *FS* = 1.3.

Reliability

Compute probability of unstable condition, P[*FS* < 1.0], due to the uncertainty of soil strength (c', ϕ'), unit weight (γ), hydraulic conductivity (K), blanket thickness (z_B), root reinforcement (C_R) and tree weight (W_t).

Fragility curve with epistemic uncertainty bands

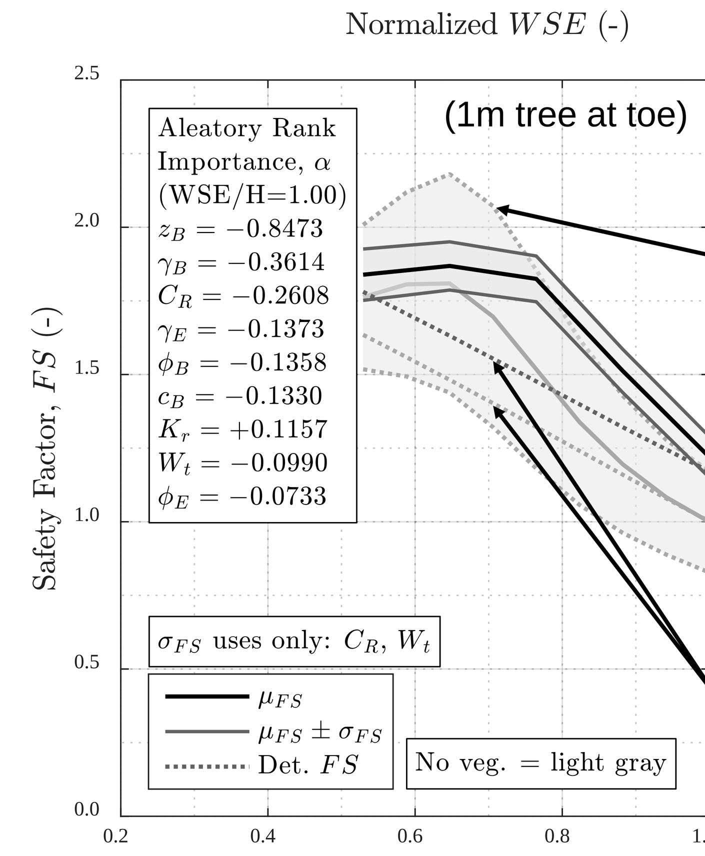


Uncertainty without tree

Reduction in *p* due to tree

Uncertainty from tree only

Mean value of FS with epistemic uncertainty bands



Uncertainty without tree

Uncertainty from tree only

Increase in μ_{FS} due to tree

Deterministic *FS* with and without tree

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Lanzafame, Teng & Sitar (2017). *Stochastic Analysis of Levee Stability Subject to Variable Seepage Conditions*. Geo-Risk 2017, ASCE.
Lanzafame (2017). *Reliability Analysis of the Influence of Vegetation on Levee Performance*. Ph.D. Dissertation, UC Berkeley, December, 2017.
Lanzafame & Sitar. *Reliability Analysis of the Influence of Vegetation on Levee Performance*. In preparation (CLVRP Report & UCB-GT/17/01).

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