Mid-Atlantic Floodplain Sediment Budgets Through Time (MAFSBETT) – Users Manual

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June 13, 2023

This document presents a brief description of the MATLAB scripts MAFSBETT. It describes variables used to control what MAFSBETT does, and includes some typical graphical output results.

Overview

The MAFSBETT model is a series of MATLAB (version R2018a) scripts that compute channel suspended sediment flux, floodplain deposition, and floodplain erosion at 3-month time intervals for a single valley reach assumed to be located within the mid-Atlantic Piedmont Province of the USA. Model computations can begin in any year, but the model is designed to operate over millennial timescales, potentially starting computations 7550 years B.P. and continuing until 2017 A.D. The model accounts for changes in storm frequency and sediment supply driven by deforestation and urban development over this period of dramatically changing land use, and it also considers the effects of mill dams on water levels upstream (if the model reach is located within the backwater zone of a mill dam).

The purpose of the model is to quantify the amount of sediment that is stored on floodplains and to determine how long sediments remain in storage before being remobilized back into the fluvial transport system. Model outputs include the elevation of the floodplain and the age and storage time distributions of floodplain sediment, all of which are updated at the end of each model time step of three months. Average annual sediment budgets can also be computed over any selected time interval. The model is "tuned" to reproduce the thicknesses of floodplain sediments deposited in the mid-Atlantic Piedmont Province from three different time periods: presettlement (before 1750), legacy (1750-1950), and modern (1950-2017).

The model itself and data used for model "tuning" are described in several publications. Field data for model calibration are presented by Pizzuto et al. (2022). The nature of mid-Atlantic stream channels and river corridors assumed by the model's structure are in part justified by Pizzuto et al. (2023). Pizzuto (in review) provide a thorough explanation of the model equations, calibration, and other details.

The primary application of MAFSBETT is to allow sediment storage on floodplains to be incorporated into watershed-scale sediment routing models. More information regarding the importance of floodplain storage in sediment routing can be found in Lauer and Parker (2008) and Pizzuto (2020).

Table 1 presents a summary of model variables and processes. Additional details are provided by Pizzuto (2023).

Table 1. Summary of model variables and processes. See Pizzuto (2023) for details.

Topic	Model procedure or implementation	Comments (none if blank)
Drainage area	Selected randomly from 26-260 km^2	
Channel width, slope	Regional hydraulic geometry equations	constant through time
Hydraulic resistance	Constant Manning's n = 0.035	
Reach location	Distance along main channel derived from drainage area via Hack's Law (Hack, 1957)	
Mill dam chronology	Mill dams present from 1800 - 1910	
Mill dam proximity	Spaced at 2 km intervals along a "main channel"	
Mill dam backwater	Dam height/river slope	
Model starting date	Selected randomly from ^{14}C database	
Model ending date	Any year after starting year and before 2017	
Initial storage	Floodplain storage = 0 at starting date	
Time step for deposition	3 months	
Time step for erosion	Integer multiple of 3 months, typically 4 years	
Storm discharge	Selected randomly from empirical flow duration curve based on drainage area, forest cover, and imperviousness	
Storm duration	Empirical relationship based on forest cover and imperviousness	
Sediment concentration	Power law rating curve	Calibrated with presettlement and legacy stratigraphic data
Water level - no mill dam	Steady uniform flow	
Water level - with mill dam	Broad-crested weir formulation	
Floodplain deposition	A function of settling velocity, concentration, and overbank flow duration	Settling velocity determined through model calibration to modern stratigraphic data
Floodplain erosion	Based on sediment storage by age	

Model Control Variables

Because MAFSBETT has been calibrated to account for changing watershed conditions of the mid-Atlantic U.S. since the mid-Holocene, only 5 variables would typically be selected by users (shaded variables in Table 2). These variables control whether or not sediment budgets are computed, the years over which sediment budget variables are averaged, the ending year for computations, and whether or not graphical output results are printed on screen at the end of the model run. A host of other variables are also listed in Table 2 that could be changed if desired.

Table 2. Model control variables. Only shaded variables need to be specified for most model runs. See Pizzuto (2023) for details.			
Variable	Routine	Line #	Comments
sediment_budget	Mid-Atlantic_floodplain_sediment_budgets_through_time	9	set = 1 to compute annual sediment budget variables
plot_graphs_on_screen	Mid-Atlantic_floodplain_sediment_budgets_through_time	12	set =1 to plot results on screen
max_age	select_time_domain_and_time_parameters	21,23	Selected randomly from ^{14}C database - starting time for computations
erosion_dt	select_time_domain_and_time_parameters	29	Years between erosion events. Typically 4.
end_year	select_time_domain_and_time_parameters	32	Year when computations end
sediment_budget_start_year	select_time_domain_and_time_parameters	58	See notes in routine
sediment_budget_end_year	select_time_domain_and_time_parameters	60	See notes in routine
drainage_area	pick_forest_and_drainage_afea	7	Selected randomly
grain_size_phi	grain_size_and_settling_velocity	2	grain size in phi units determined by model calibration
pre_settlement_sediment_rating_curve_multiplier	sed_rating_curve_and_erosion_multipliers_through_time	9	determines presettlement sediment concentration - set by calibration
modern_sediment_rating_curve_multiplier	sed_rating_curve_and_erosion_multipliers_through_time	10	determines legacy sediment concentration - set by calibration
legacy_sediment_rating_curve_multiplier	sed_rating_curve_and_erosion_multipliers_through_time	11	determines modern sediment concentration - known from data
pre_settlement_erosion_multiplier	sed_rating_curve_and_erosion_multipliers_through_time	13	assumed = 1
legacy_erosion_multiplier	sed_rating_curve_and_erosion_multipliers_through_time	14	assumed = 1
modern_erosion_multiplier	sed_rating_curve_and_erosion_multipliers_through_time	15	known from data

Example Model Results

Figures 1-4 present results of an example model run, with selected model variables summarized in Table 3. Figure 1 illustrated changing floodplain elevation through time, while Figure 2 presents the stored sediment residence time through time. The age distributions of stored sediment obtained at the end of the model run in 2017 are presented in Figures 3 (age probability density function) and 4 (age exceedance function).

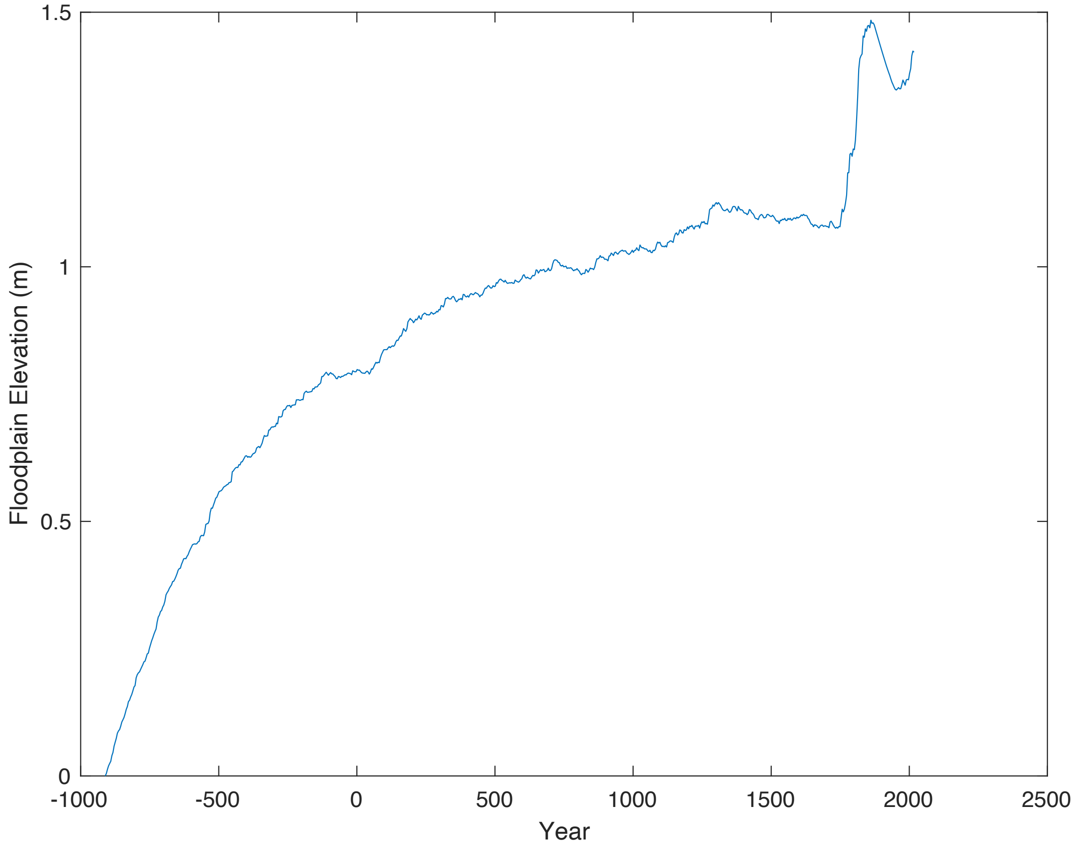

Figure 1. Floodplain elevation through time.

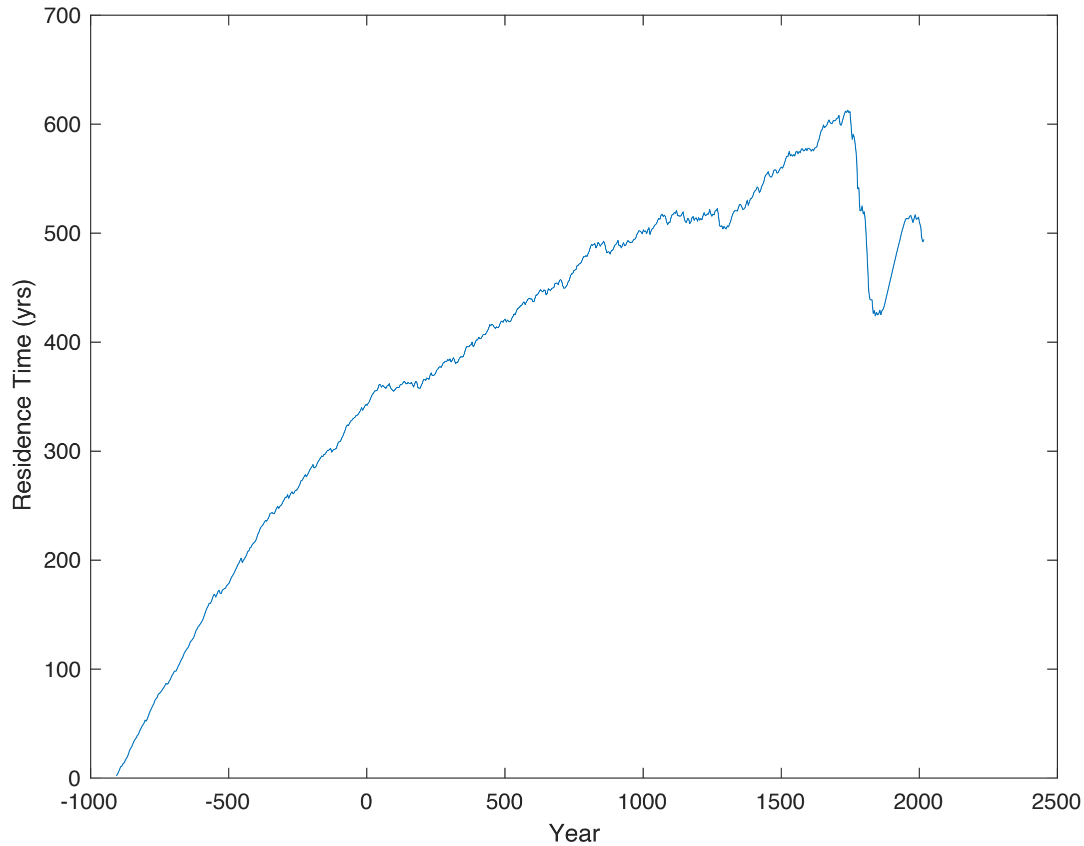

Figure 2. Residence time of stored sediment as a function of time.

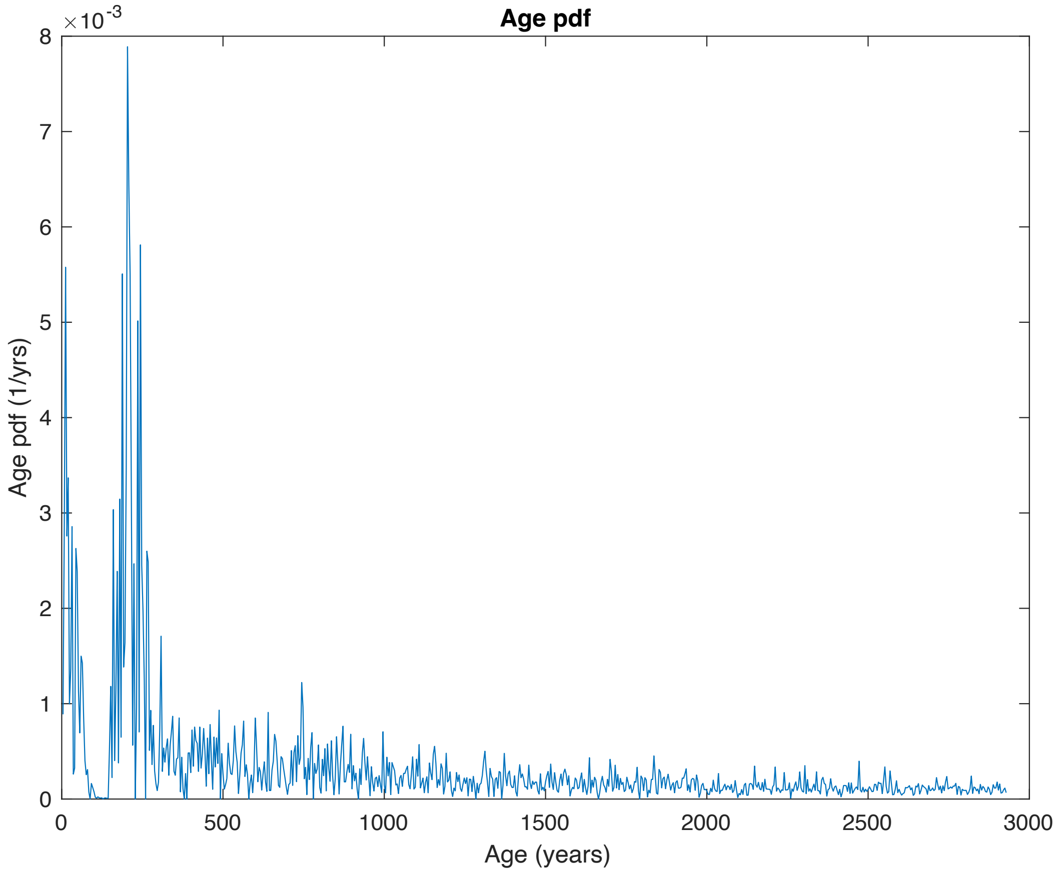

Figure 3. Age probability density function of stored floodplain sediment computed at the end of the model run in 2017.

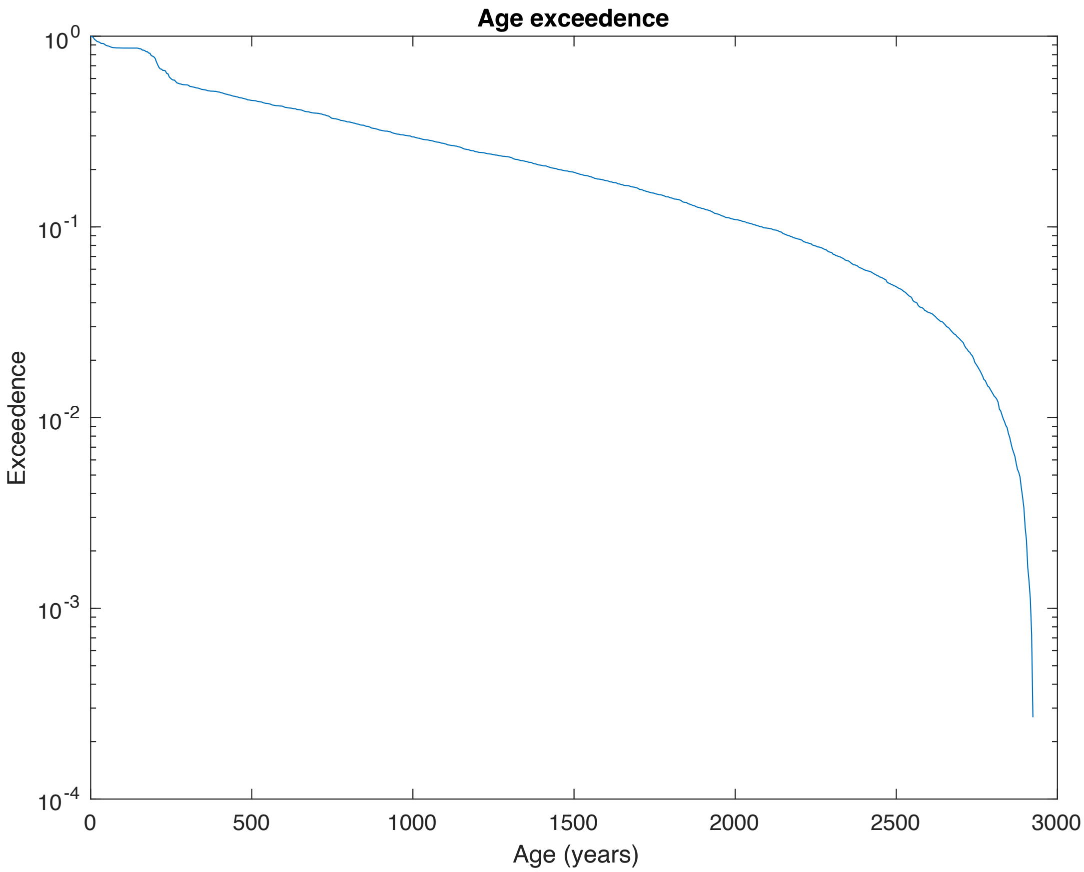

Figure 4. Exceedence curve of stored sediment ages computed at the end of the model run in 2017.

Table 3. Selected variables of the example model run illustrated in Figures 1-4.		
Variable	Value	Comments
max_age	2928	Years since 2017
start_year	-911	Years A.D.
end_year	2017	Years A.D.
drainage_area	238	km^2
erosion_dt	4	Interval between erosion events (yr)
grain_size_phi	7.5	
imperv_1970	0.82	watershed imperviousness in 1970
imperv_1985	1.2	watershed imperviousness in 1985
imperv_1997	7.5	watershed imperviousness in 1997
imperv_2010	34.4	watershed imperviousness in 2010
legacy_erosion_multiplier	1	
legacy_sediment_rating_curve_multiplier	1	
milldam_influence	0	model reach not impacted by mill dam
modern_erosion_multiplier	1	
modern_sediment_rating_curve_multiplier	1	
pct_forest_1950	22.5	% forest in watershed in 1950
pre_settlement_erosion_multiplier	1	
pre_settlement_sediment_rating_curve_multiplier	1	

References

Hack, J.T. (1957), Studies of longitudinal stream profiles in Virginia and Maryland. *U.S. Geological Survey Professional Paper 294-B,* 97 p.

Lauer, J.W., and Parker, G. (2008), Modeling framework for sediment deposition, storage, and evacuation in the floodplain of a meandering river: Theory. *Water Resources Research*, 44, W04425, doi:10.1029/2006WR005528.

Pizzuto, J. (2020), Suspended sediment and contaminant routing with alluvial storage: new theory and applications. *Geomorphology*, 352, doi:10.1016/j/geomorph.2019.106983.

Pizzuto, J.E., Skalak, K., Benthem, A., Mahan, S.M., Sturchio, N., & Pearson, A. (2022) , Spatially averaged stratigraphic data to inform watershed sediment routing: an example from the Mid-Atlantic United States. *Geological Society of America Bulletin*, doi:10.1130/B36282.1.

Pizzuto, J.E., Huffman, M.E., & Symes, E. (2023), Pre- and postsettlement depositional processes and environments of the 3^{rd} to 5^{th}-order White Clay Creek watershed, Piedmont Provide, Pennsylvania and Delaware, USA. *Geological Society of America Bulletin*, https://doi.org/10.1130/B37032.1.