An overview of the methods used to simulate potentially available woody debris (AFLWD) and shade

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Introduction

- Objectives
  - Provide an overview of the rationale and methods used to obtain AFLWD volume and piece count estimates
  - Provide overview of methods for shade estimates
- Two parts:
  - Part 1: AFLWD and shade model rationale
  - Part 2: AFLWD and shade model steps

AFLWD Model Rationale

- We don’t know which trees will fall and enter a stream or when they will fall
- We know that regular mortality is *not* the only source of LWD that could enter a stream
- We know that the trees located closer to a stream are more likely to fall and enter it than are trees further away
- We know that trees adjacent to a stream are the source of LWD within a watershed
- Trees closer to a stream produce larger pieces of LWD

AFLWD Model Rationale (cont)

- AFLWD assumptions:
  - LWD recruited to a stream must come from adjacent forests within its watershed
  - The standing trees, therefore, become the source for future LWD logs
  - Standing live trees were chosen for AFLWD
    - Ease of use with growth models
    - Ease of identification and measurement by landowners

AFLWD Model Rationale (cont)

- AFLWD assumption (cont):
  - What about snags?
    - Snags and fallen trees were standing live trees at some point, and get considered when they were live trees
    - Snags make up a small percentage of the standing wood (Ohmann and Wadell, 2002)
    - Snags contribute less to functional LWD because they are already partially decomposed when they fall

AFLWD Model Rationale (cont)

- Amounts of instream LWD are highly variable both temporally and spatially
  - A myriad of input processes (wind, landslides, erosion) and transport, decay, etc.
- Mass or volume balance approaches to instream LWD may not be applicable
  - Very general and difficult to validate
  - Individual trees are not directly represented, but they are the relevant entities that should be modeled and measured

AFLWD Model Rationale (cont)

- AFLWD assumptions
  - Don’t model in stream LWD
  - Model instead the potential for instream LWD from the pool of available (standing live) trees in the adjacent forest
  - Use the individual trees and their volumes rather than volume or biomass alone
    - This includes the discrete nature of the trees and their mass or volume, both of which are relevant

AFLWD Model Rationale (cont)

- Tree fall directions may be preferential toward a stream
  - Particularly for wider streams
- AFLWD assumptions
  - Trees fall perpendicularly toward a stream
  - Trees fall independently of one another
  - Look at random fall as well to obtain a lower bound

AFLWD Model Rationale (cont)

- There may be a size (volume) piece count trade off, particularly for larger streams
  - Volume or piece size may be more important than number of pieces for “quality” LWD
- AFLWD assumptions
  - Don’t include breakage
    - Compute estimates of both volume and number of pieces
    - Piece counts may be low

AFLWD Model Rationale (cont)

- Instream LWD logs must be defined using the stream bank as a point of reference
  - How much of the log on the bank should count? In the stream?
  - While some data have been collected they have typically not been published.
- AFLWD assumption
  - Define potential LWD logs relative to the point of intersection with the nearest stream bank

Shade Model Rationale

- Model blocking factor, not shade
  - Easier then shade
  - Don’t need to track sun position
  - Don’t need stream orientation
  - Don’t need to account for seasonality
    - This is possible, if desirable, for deciduous or mixed forests
- Blocking factor is the ratio of obstructed light input over unobstructed light input

Shade Model Rationale (cont)

- Assumes a fixed point in the center of a stream
- Generate uniformly distributed points on the surface of a unit hemisphere located at the center of the stream
- Project rays through the points, outward through the forest
- Assumes a sinusoidal reduction in input energy from the zenith to the horizon

Shade Model Rationale (cont)

- Two versions
  1. Uniform slabs to represent volumes with differing forest and light transmission characteristics
  2. Individual tree based slabs, with crowns and boles having different light transmission characteristics
- Version 1 is similar to the RAIS shade/blocking model

AFLWD Model Steps

- Specify the inputs
  - A tree list: DBH, height, TPA and species.
    - Forest model output or actual
    - All trees were assumed to have a single bole
    - A taper equation for Douglas fir (Kozak, 1988) was used to compute volumes for all trees
  - The modeled area
    - A one acre area with a width of 170 ft and a reach of 256.2 ft adjacent to a stream
  - Minimum diameters, lengths for LWD log sizes

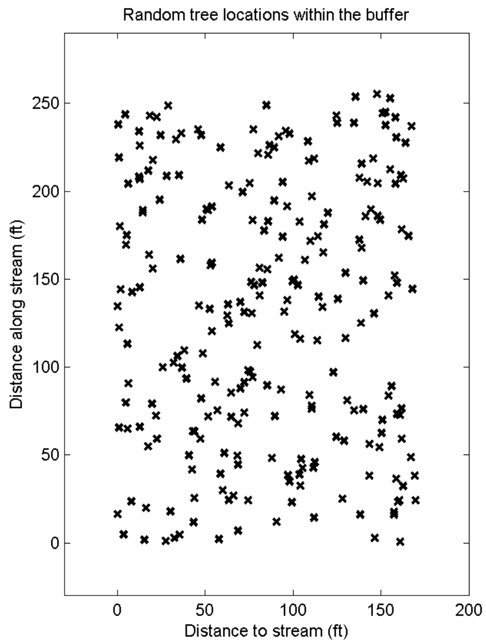
AFLWD Model Steps (cont)

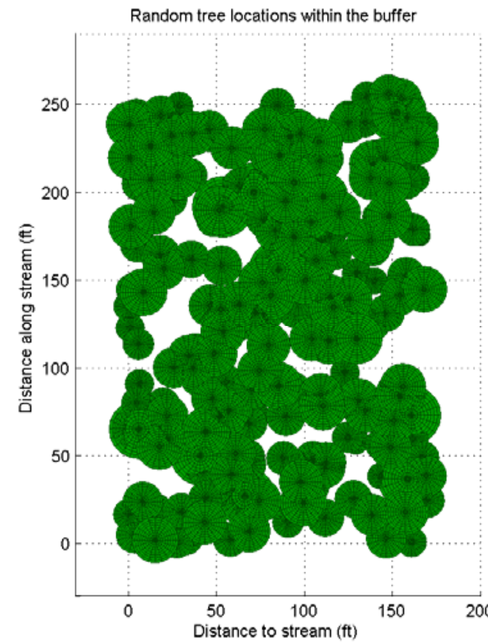
- Stream sizes and minimum LWD characteristics

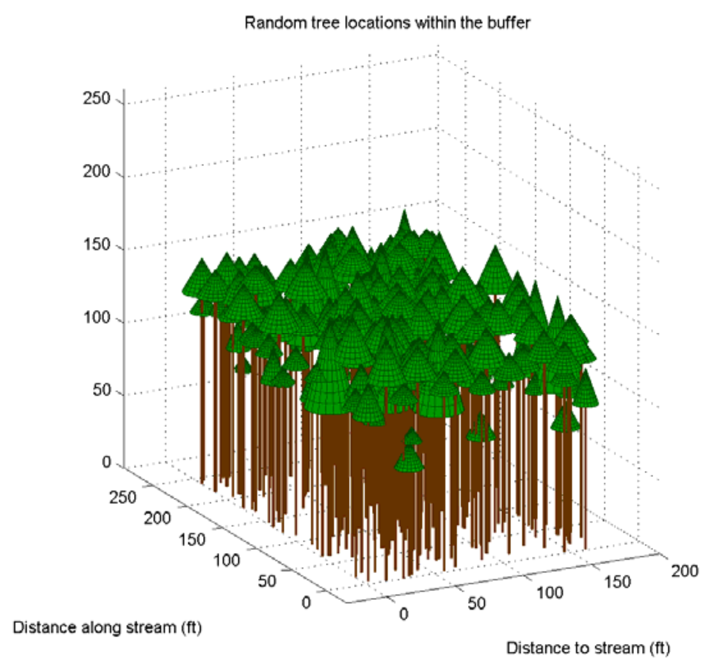
Stream class	Bank full width (ft)	Minimum diameter (in)	Minimum length (ft)
A	75.0	25.6	44.0
B	30.0	10.3	24.5
C	15.0	5.3	15
D	7.5	4.0	7.5
E	5.0	4.0	6.6

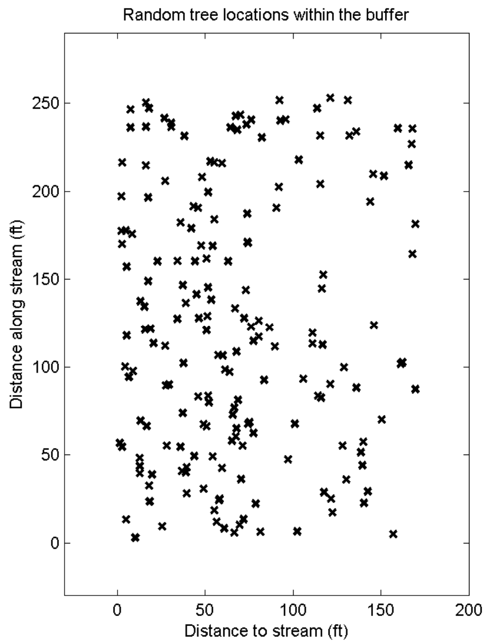
AFLWD Model Steps (cont)

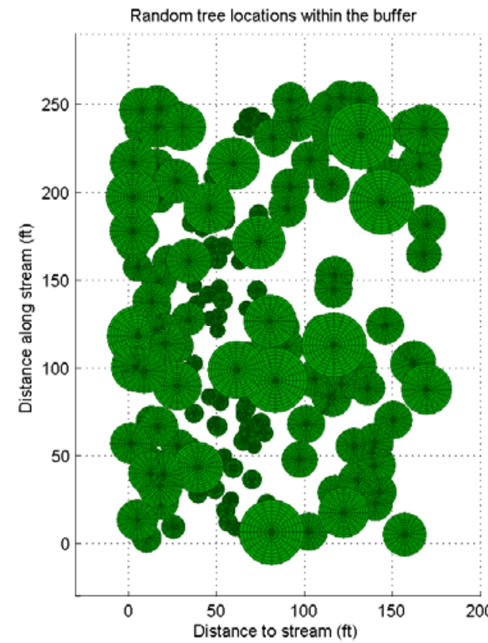
- Step 1: Expand the tree list into individual trees having TPA values ≤ 1
  - Replicate each tree having a TPA value > 1
    - Obtain whole trees having TPA values of 1
    - If there is a fractional remainder, include this too using a fractional TPA value (TPA < 1)
- Step 2: Randomly (uniformly) assign trees within the modeled area or buffer zone
  - Only need distance from stream for AFLWD
  - Location along the stream was also assumed to be random, needed for shade/blocking

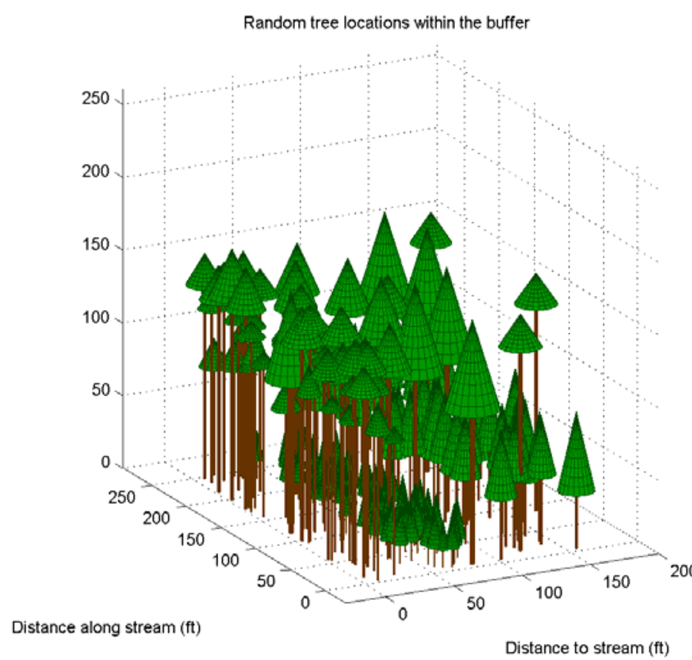

Random tree locations within the buffer
Distance along stream (ft)
Distance to stream (ft)
0
50
100
150
200
250


Random tree locations within the buffer
Distance along stream (ft)
Distance to stream (ft)
0
50
100
150
200
250


Random tree locations within the buffer
Distance along stream (ft)
Distance to stream (ft)
0
50
100
150
200
250

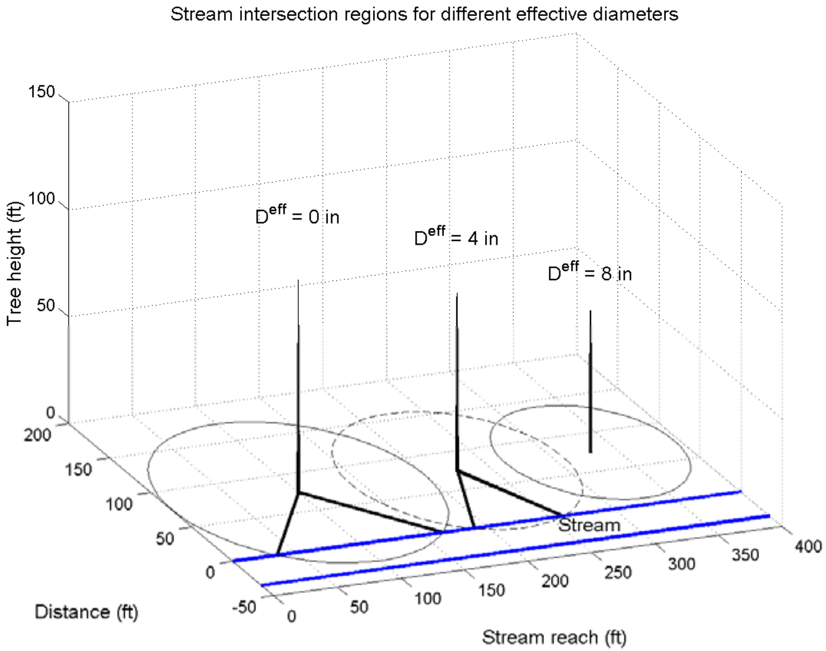

Random tree locations within the buffer
Distance along stream (ft)
Distance to stream (ft)
0
50
100
150
200
250
0
50
100
150
200

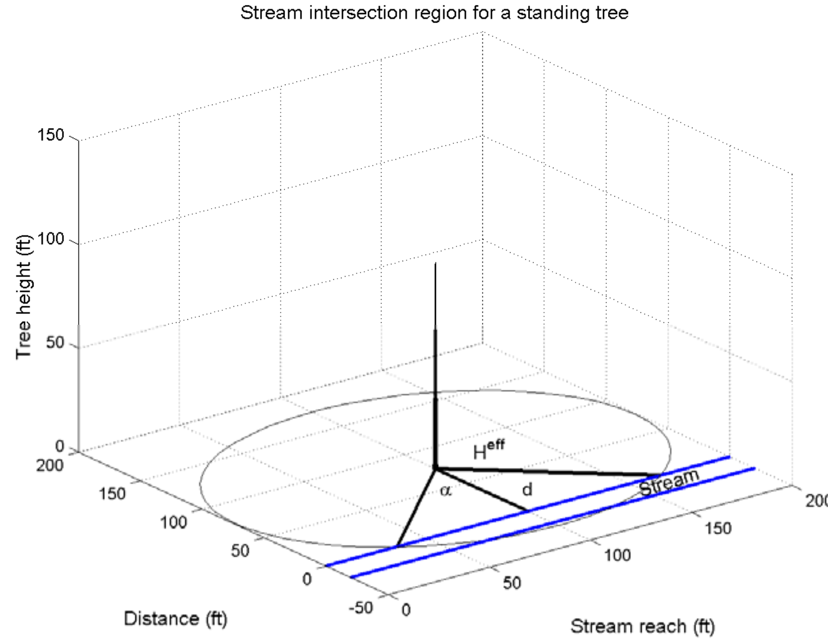

Random tree locations within the buffer
Distance along stream (ft)
Distance to stream (ft)
0
50
100
150
200
250
0
50
100
150
200

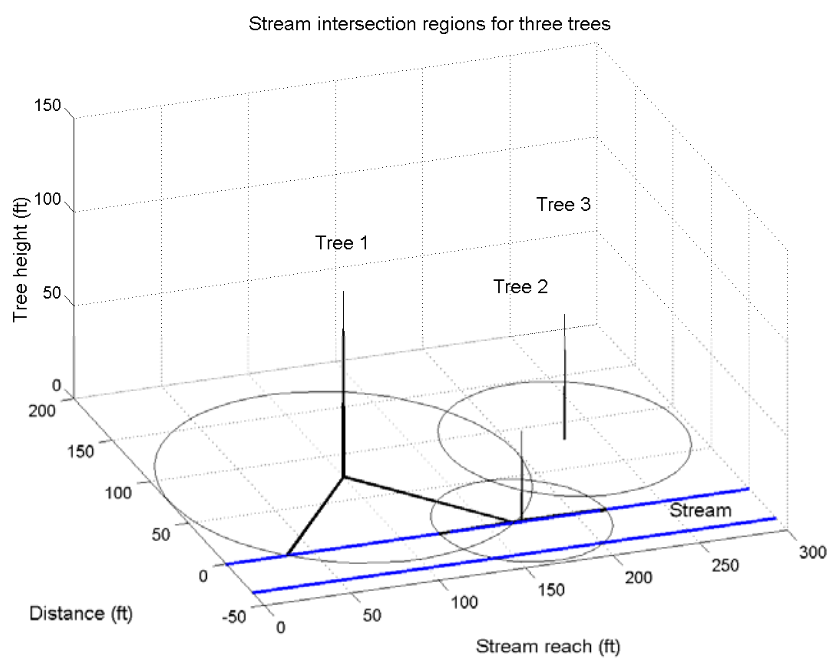

Random tree locations within the buffer
0
50
100
150
200
250
Distance along stream (ft)
Distance to stream (ft)
0
50
100
150
200

AFLWD Model Steps (cont)

- Step 3: Compute the effective tree height and the limiting stream intersection angle α for each tree
  - Effective height was the height to a 4 inch upper stem diameter, the effective diameter

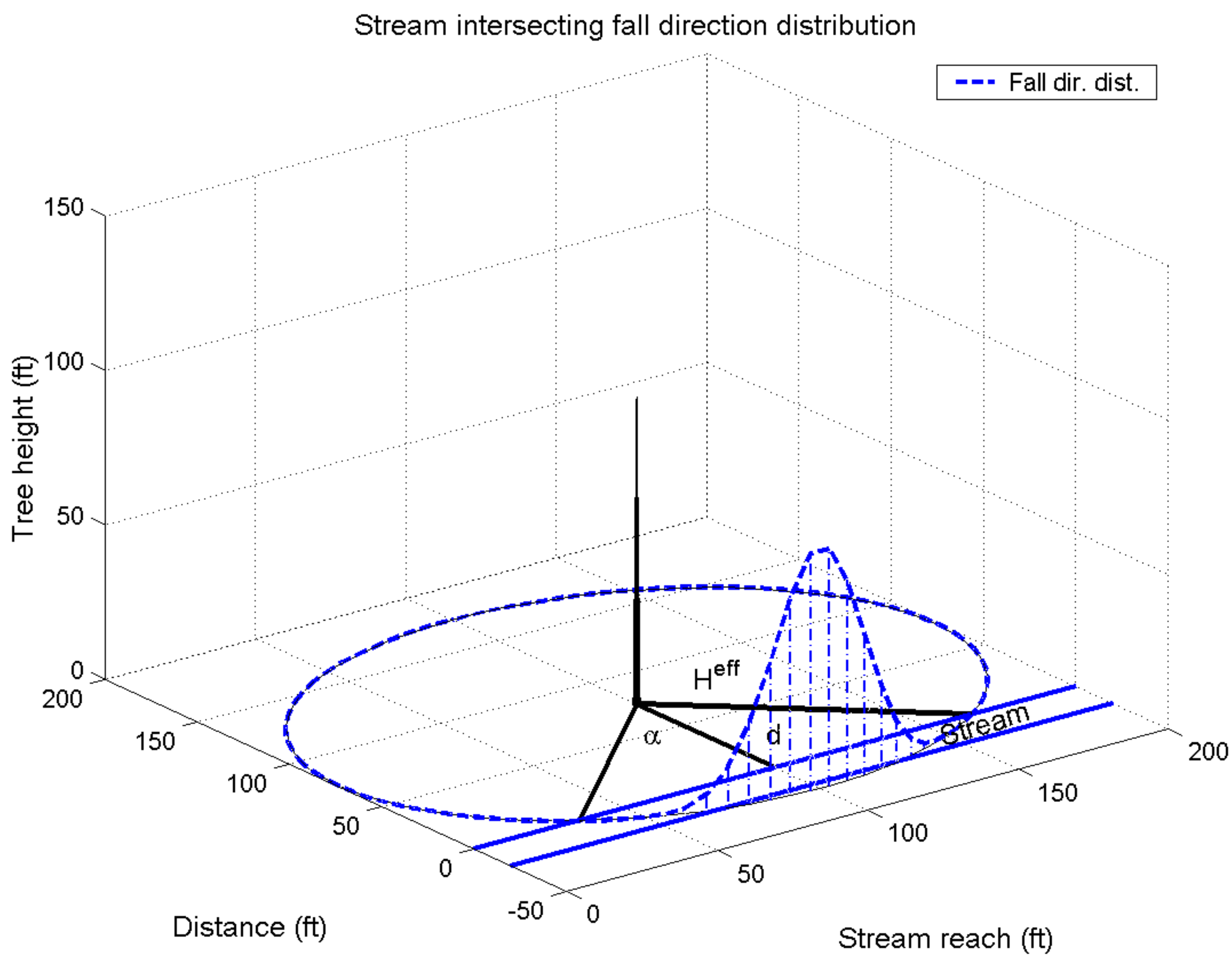

Stream intersection regions for different effective diameters
Tree height (ft)
Distance (ft)
Stream reach (ft)
D^eff = 0 in
D^eff = 4 in
D^eff = 8 in
Stream


Stream intersection region for a standing tree
Tree height (ft)
Distance (ft)
Stream reach (ft)
H^eff
α
d
Stream


Stream intersection regions for three trees
Tree height (ft)
Distance (ft)
Stream reach (ft)
Tree 1
Tree 2
Tree 3
Stream

AFLWD Model Steps (cont)

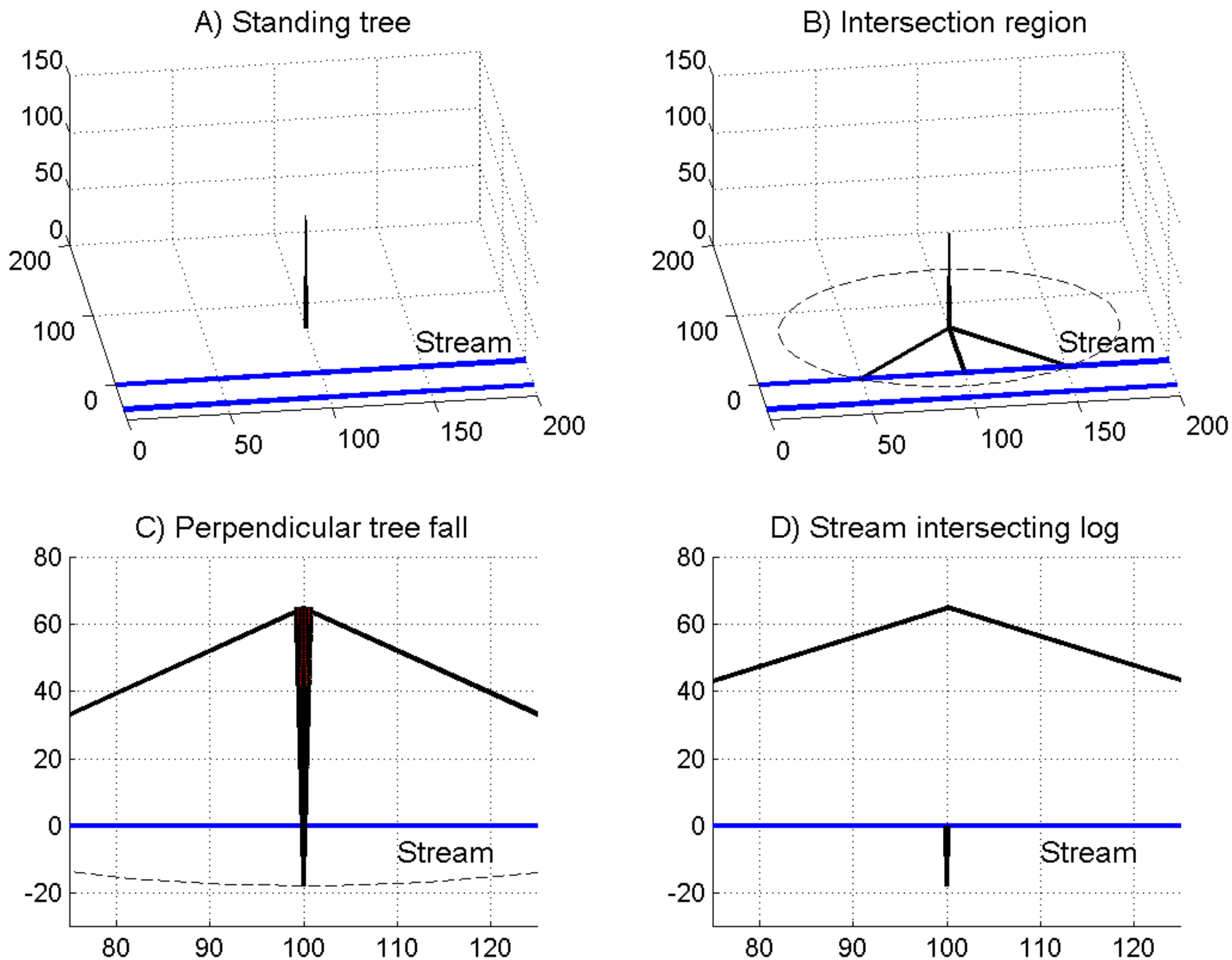
- Step 4: Compute the probability of stream intersection for each tree
  - A uniform fall direction distribution was assumed
  - The probability of stream intersection is then $\alpha/180$ for angles measured in degrees



Stream intersecting fall direction distribution
Fall dir. dist.
Tree height (ft)
150
100
50
0
200
150
100
50
0
-50
Distance (ft)
0
50
100
150
200
Stream reach (ft)
H^eff
α
d
Stream

AFLWD Model Steps (cont)

- Step 5: Assign a stream intersecting fall direction to each tree
  - Assumed to be perpendicular to stream
  - Random (uniform) within (-α, α) gives lower bound
- Step 6: Compute the dimensions and volume of the stream intersecting logs
  - Point of near bank intersection is assumed to be the base of the log



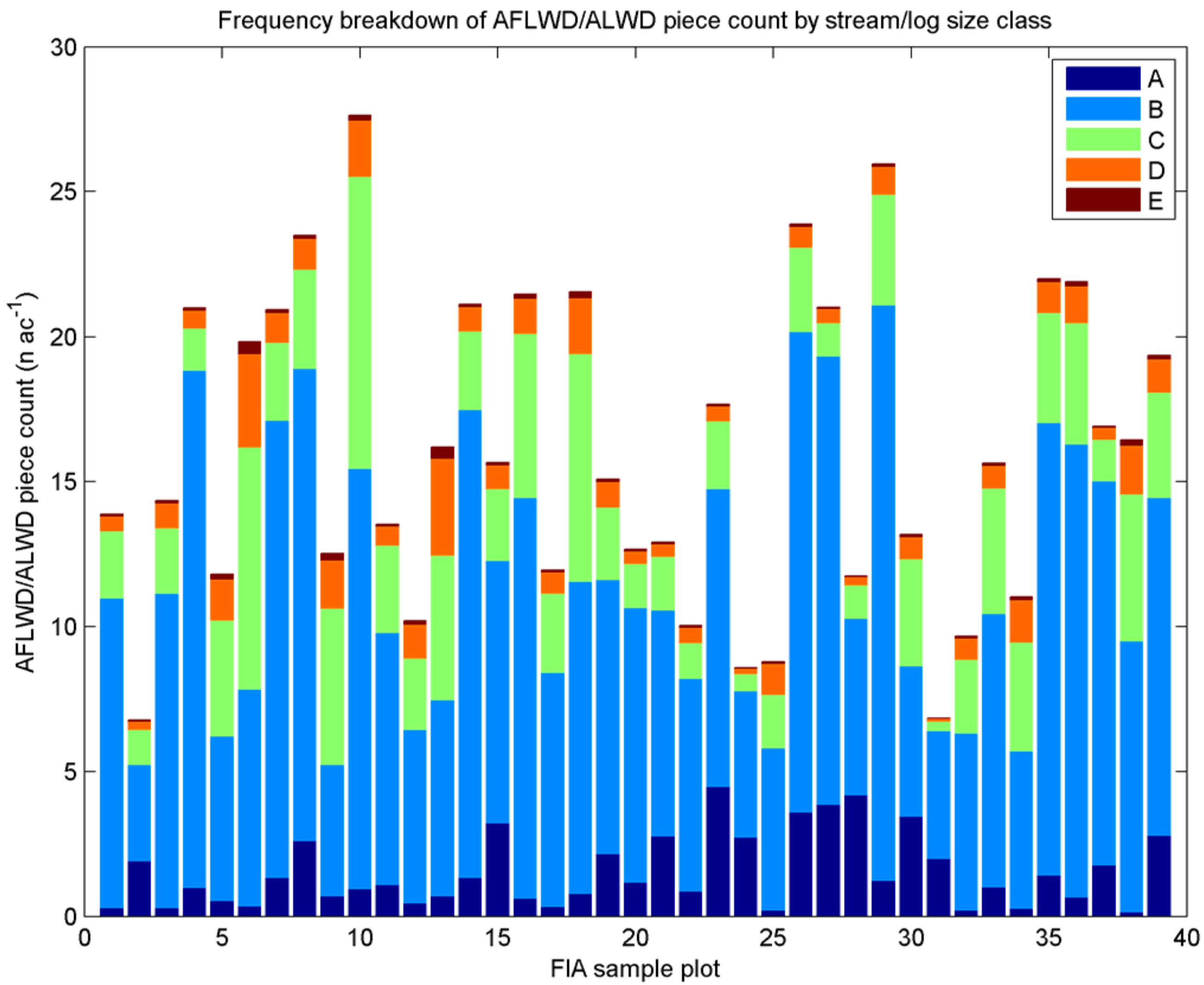
A) Standing tree
150
100
50
0
200
100
0
Stream
0
50
100
150
200
B) Intersection region
150
100
50
0
200
100
0
Stream
0
50
100
150
200
C) Perpendicular tree fall
80
60
40
20
0
-20
Stream
80
90
100
110
120
D) Stream intersecting log
80
60
40
20
0
-20
Stream
80
90
100
110
120

AFLWD Model Steps (cont)

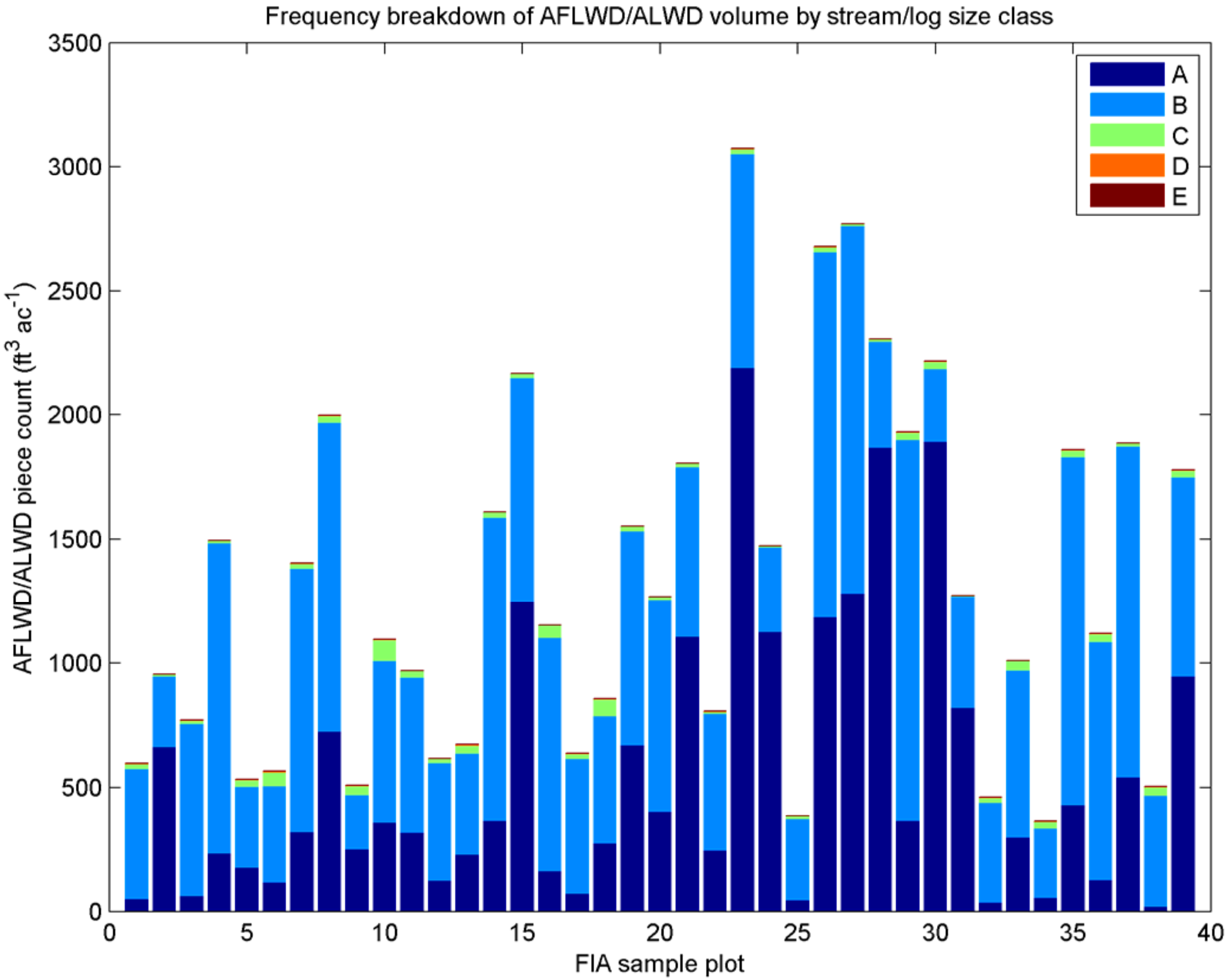
- Step 7: Compute the expected AFLWD contribution for each tree using the probability of stream intersection
- Step 8: Sum the expected values filtering by the minimum dimensions specified for each size class
  - This gives frequency/volume by size class
- Step 9: Repeat steps 1-8 the desired number of times and compute the desired statistics

AFLWD Model Validation

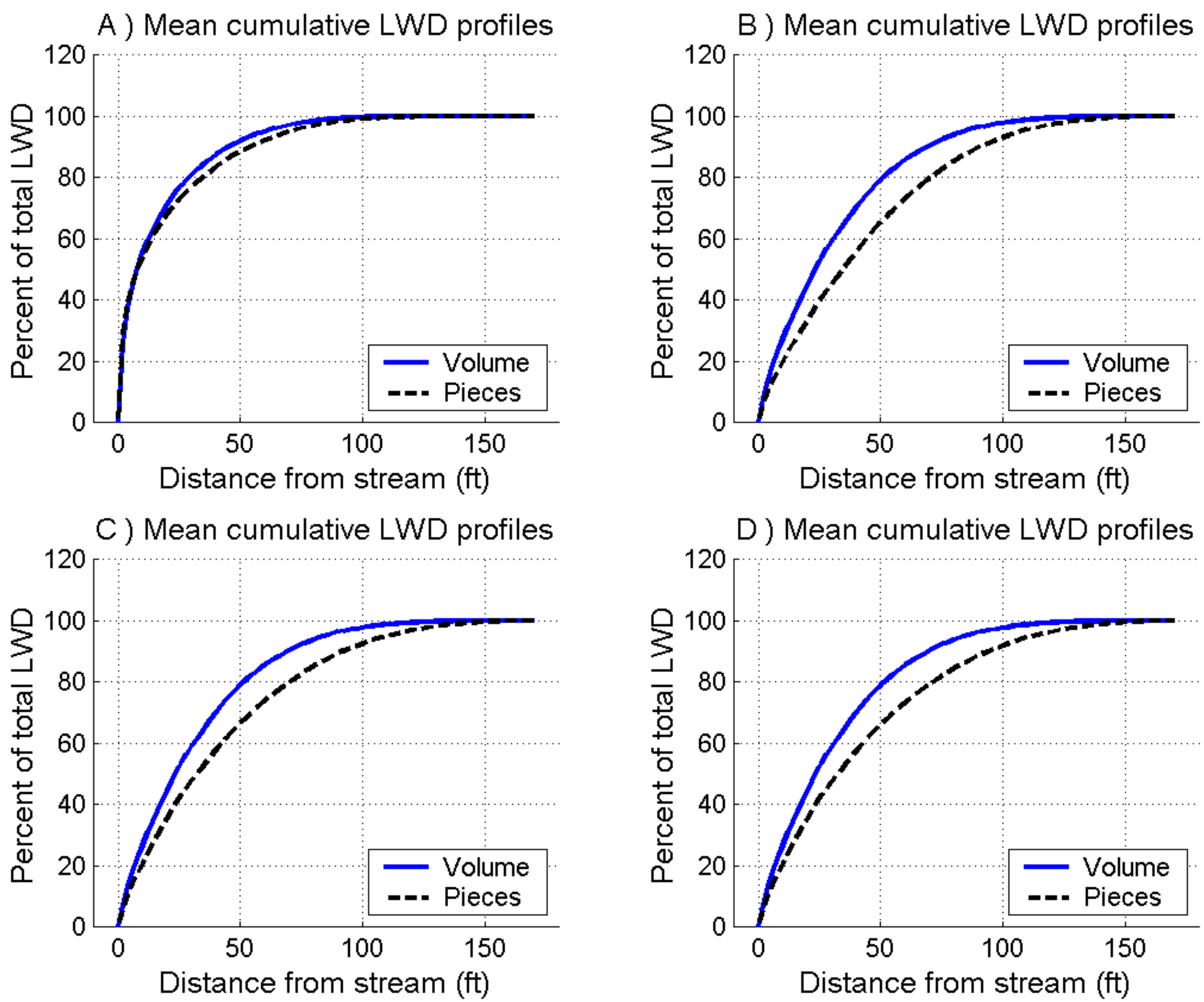
- Data used were sample plots from the FIA IDB version 1.4
- Computed source distance profiles and compared them to published results
- Compared piece counts to published empirical results
- Examined ALWD distributions by plot to assess piece count/volume trade-offs



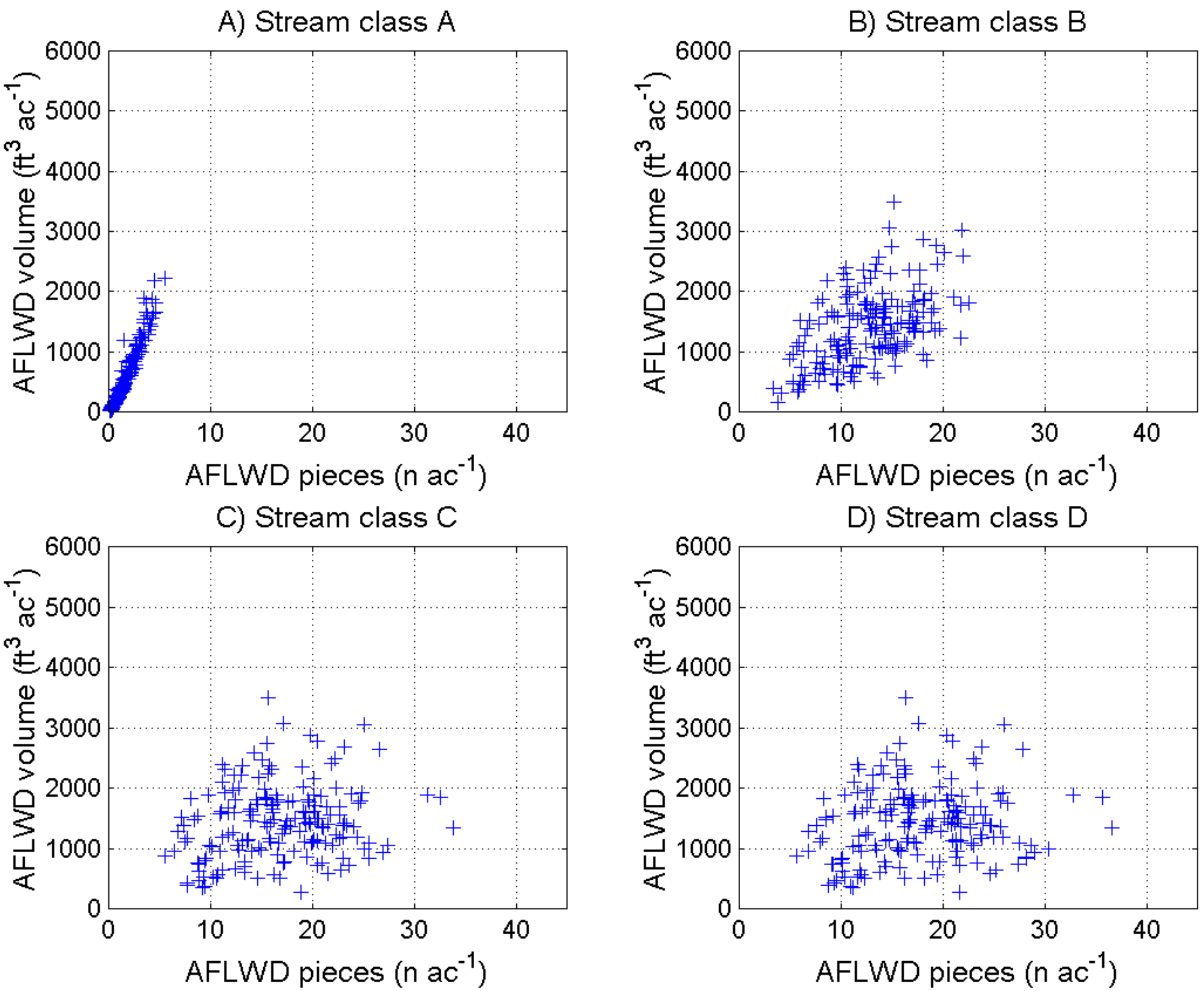
Frequency breakdown of AFLWD/ALWD piece count by stream/log size class
AFLWD/ALWD piece count (n ac^{-1})
FIA sample plot
A
B
C
D
E
0
5
10
15
20
25
30
35
40



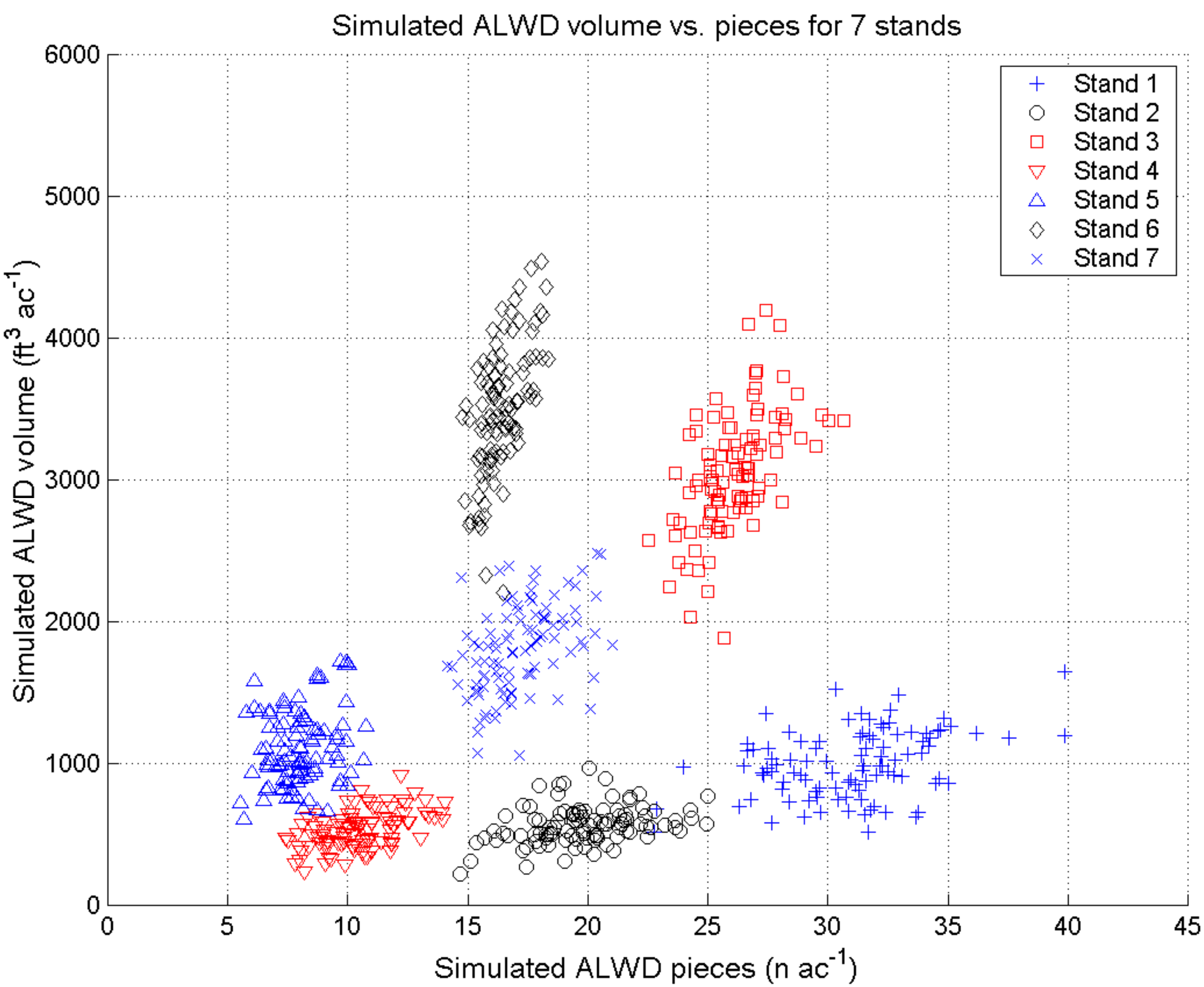
Frequency breakdown of AFLWD/ALWD volume by stream/log size class
AFLWD/ALWD piece count (ft^3 ac^{-1})
FIA sample plot
A
B
C
D
E
0
500
1000
1500
2000
2500
3000
3500
0
5
10
15
20
25
30
35
40



A) Mean cumulative LWD profiles
B) Mean cumulative LWD profiles
C) Mean cumulative LWD profiles
D) Mean cumulative LWD profiles
Percent of total LWD
Distance from stream (ft)
Volume
Pieces
0
20
40
60
80
100
120
0
50
100
150



A) Stream class A
B) Stream class B
C) Stream class C
D) Stream class D
AFLWD volume (ft^3 ac^{-1})
AFLWD pieces (n ac^{-1})
0
1000
2000
3000
4000
5000
6000
0
10
20
30
40



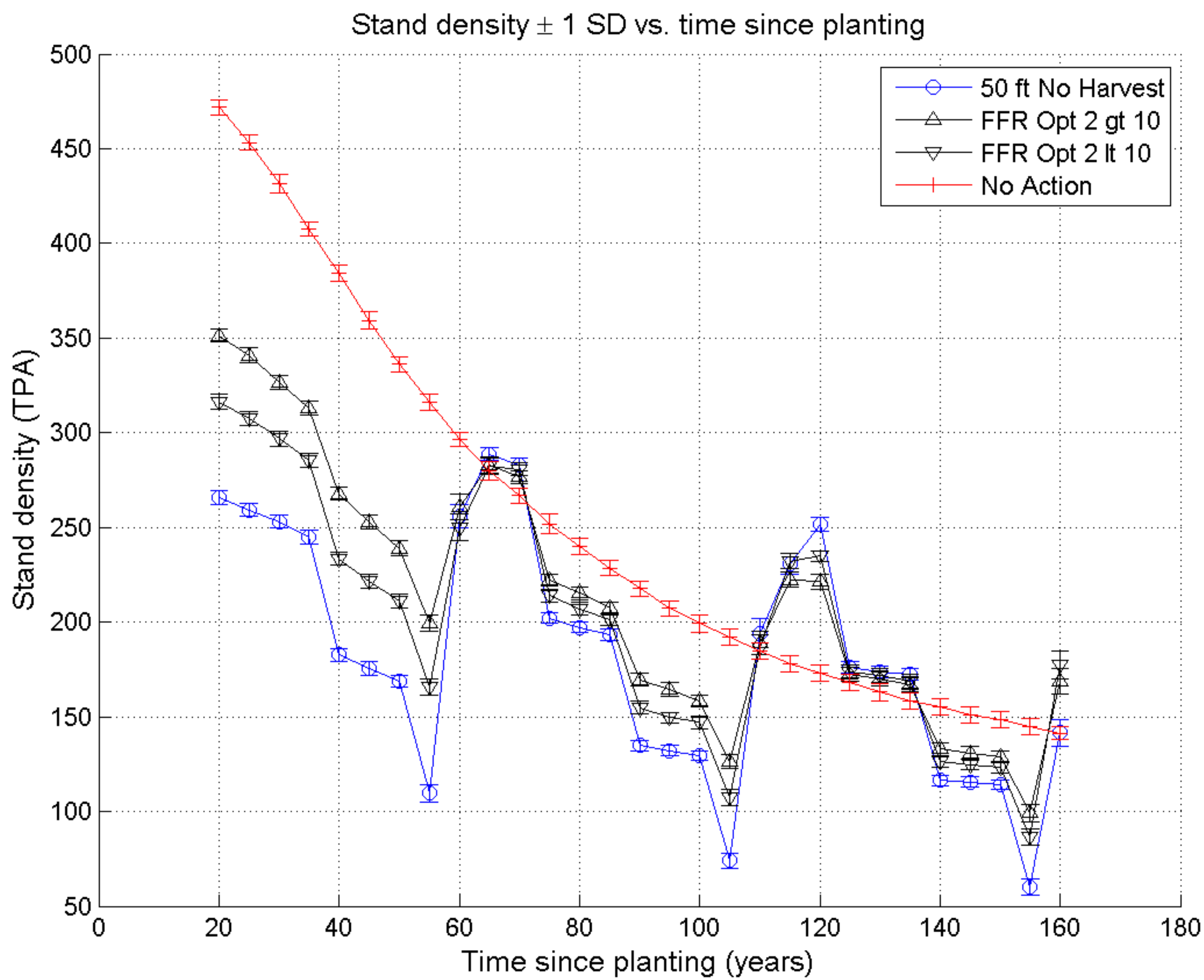
Simulated ALWD volume vs. pieces for 7 stands
Simulated ALWD volume (ft3 ac-1)
Simulated ALWD pieces (n ac-1)
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
40
45
Stand 1
Stand 2
Stand 3
Stand 4
Stand 5
Stand 6
Stand 7

Stand attributes and simulated potentially available LWD volumes and piece counts for seven sample stands.

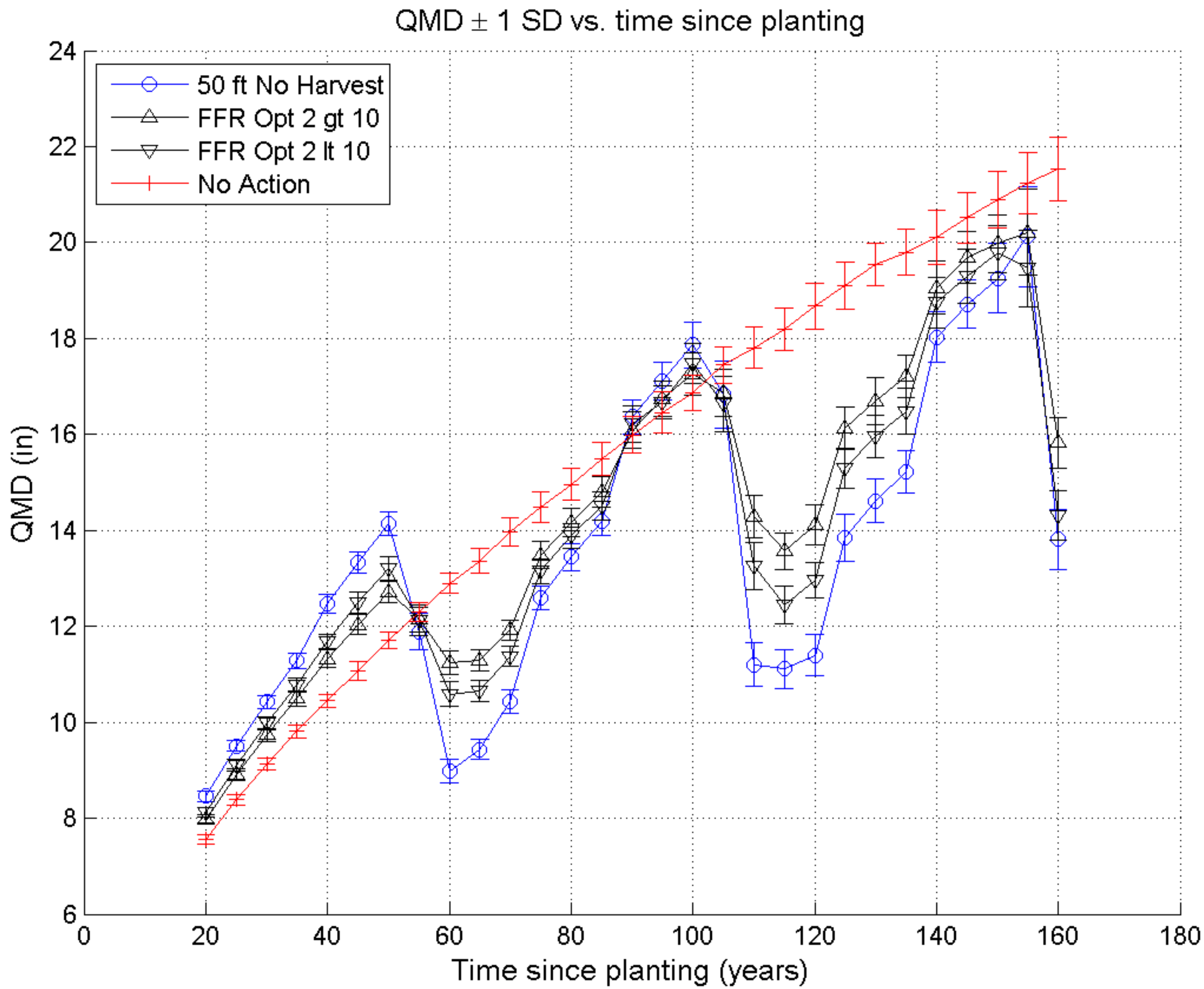
Stand	TPA	QMD (in)	H (ft)	Total BA (ft^2ac^{-1})	Total volume (ft^3ac^{-1})	ALWD pieces ($n\ ac^{-1}$)	ALWD volume (ft^3ac^{-1})
1	476.7	11.3	52.3	331.3	11916.6	30.9	995.0
2	312.7	11.6	50.1	230.0	7697.0	19.8	566.9
3	128.2	24.1	124.5	404.9	23513.5	26.1	3056.1
4	128.9	13.0	63.0	118.9	5336.2	10.4	533.6
5	63.4	22.0	86.0	167.9	8597.8	8.0	1101.4
6	70.2	29.4	148.2	330.7	22655.9	16.4	3495.1
7	164.2	17.5	75.7	275.0	14425.4	17.2	1811.8

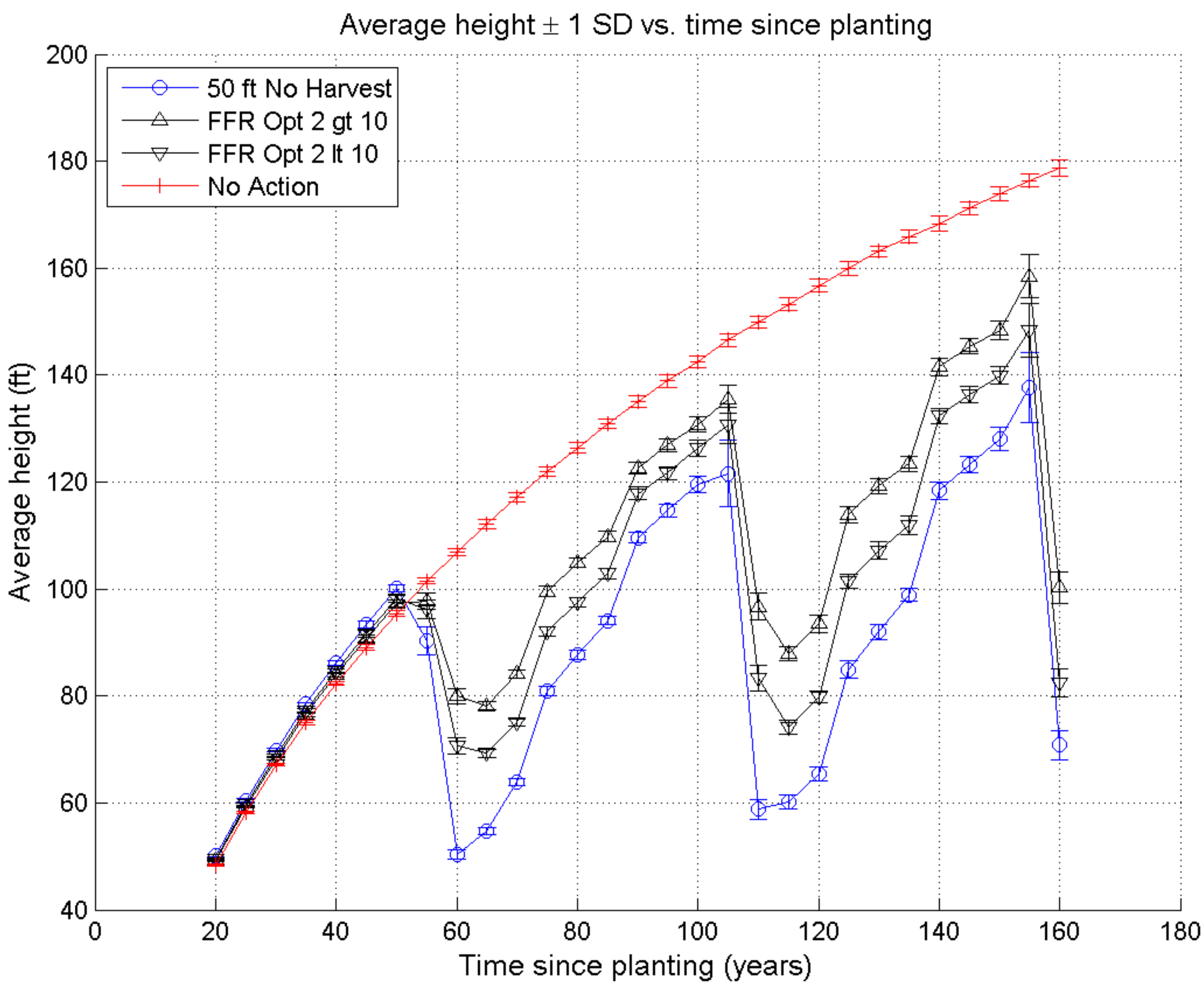
Riparian Simulation Example

- Four treatments for a 170 foot wide 256.2 foot long 1 acre buffer zone at age 80
  - 170 foot no action
  - 50 foot no harvest buffer with 50 year rotation from 50 to 170 feet
  - FFR option 2 for stream BFW < 10 feet
  - FFR option 2 for stream BFW> 10 feet
    - For the FFR options, trees were randomly located post harvest, not closer to the stream

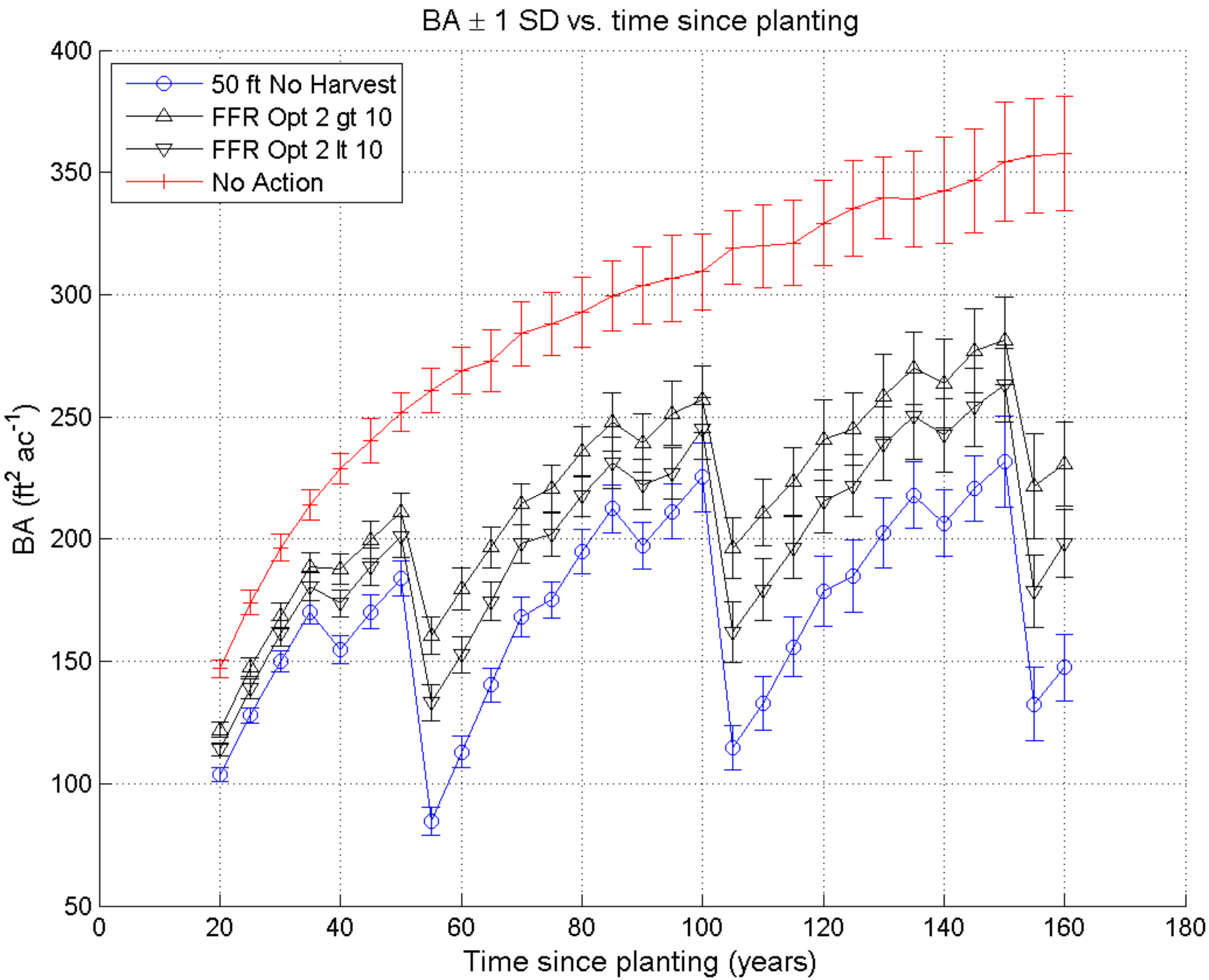


Stand density ± 1 SD vs. time since planting
Stand density (TPA)
Time since planting (years)
50 ft No Harvest
FFR Opt 2 gt 10
FFR Opt 2 lt 10
No Action
500
450
400
350
300
250
200
150
100
50
0
20
40
60
80
100
120
140
160
180

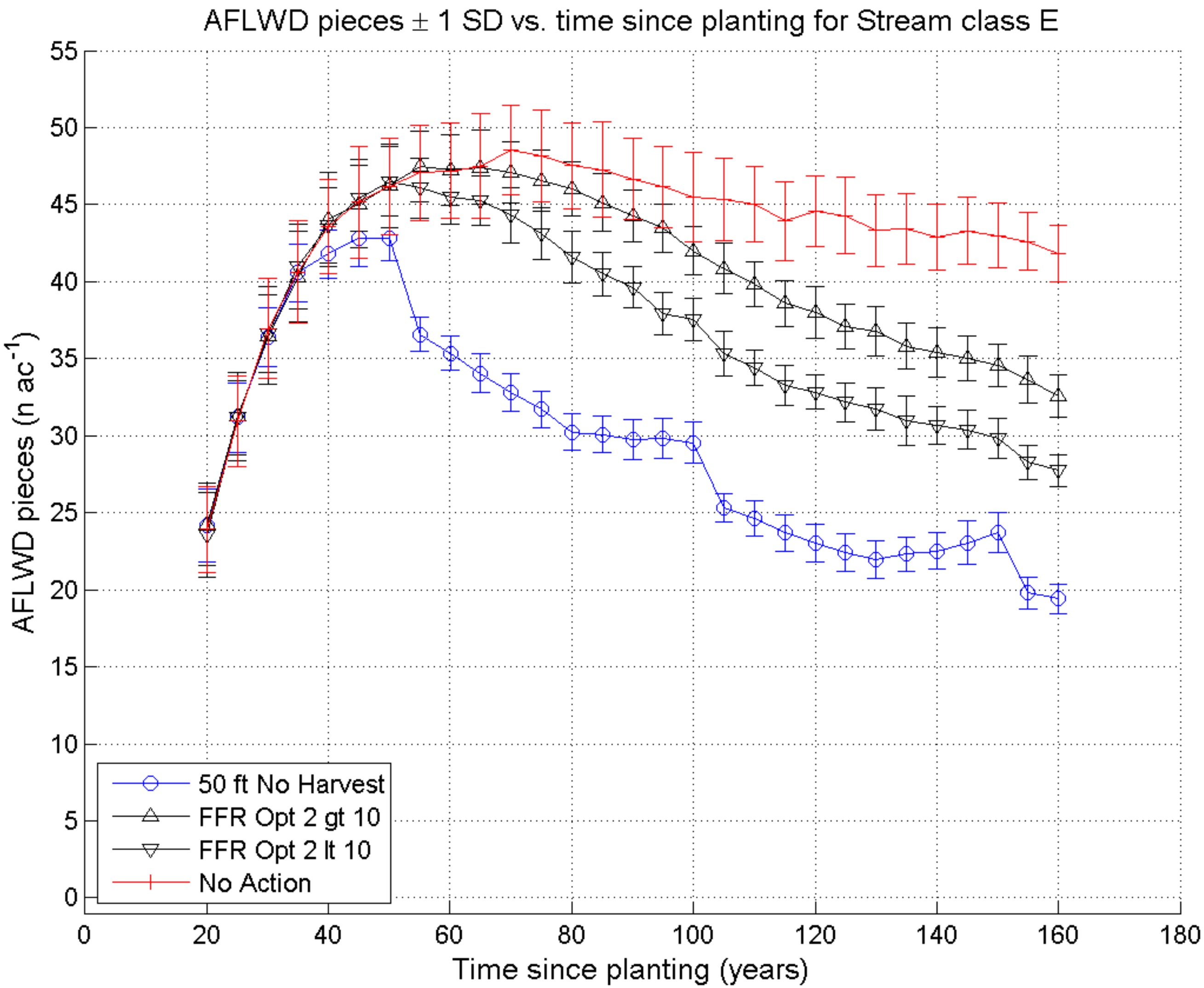

QMD ± 1 SD vs. time since planting
50 ft No Harvest
FFR Opt 2 gt 10
FFR Opt 2 lt 10
No Action
QMD (in)
Time since planting (years)
6
8
10
12
14
16
18
20
22
24
0
20
40
60
80
100
120
140
160
180

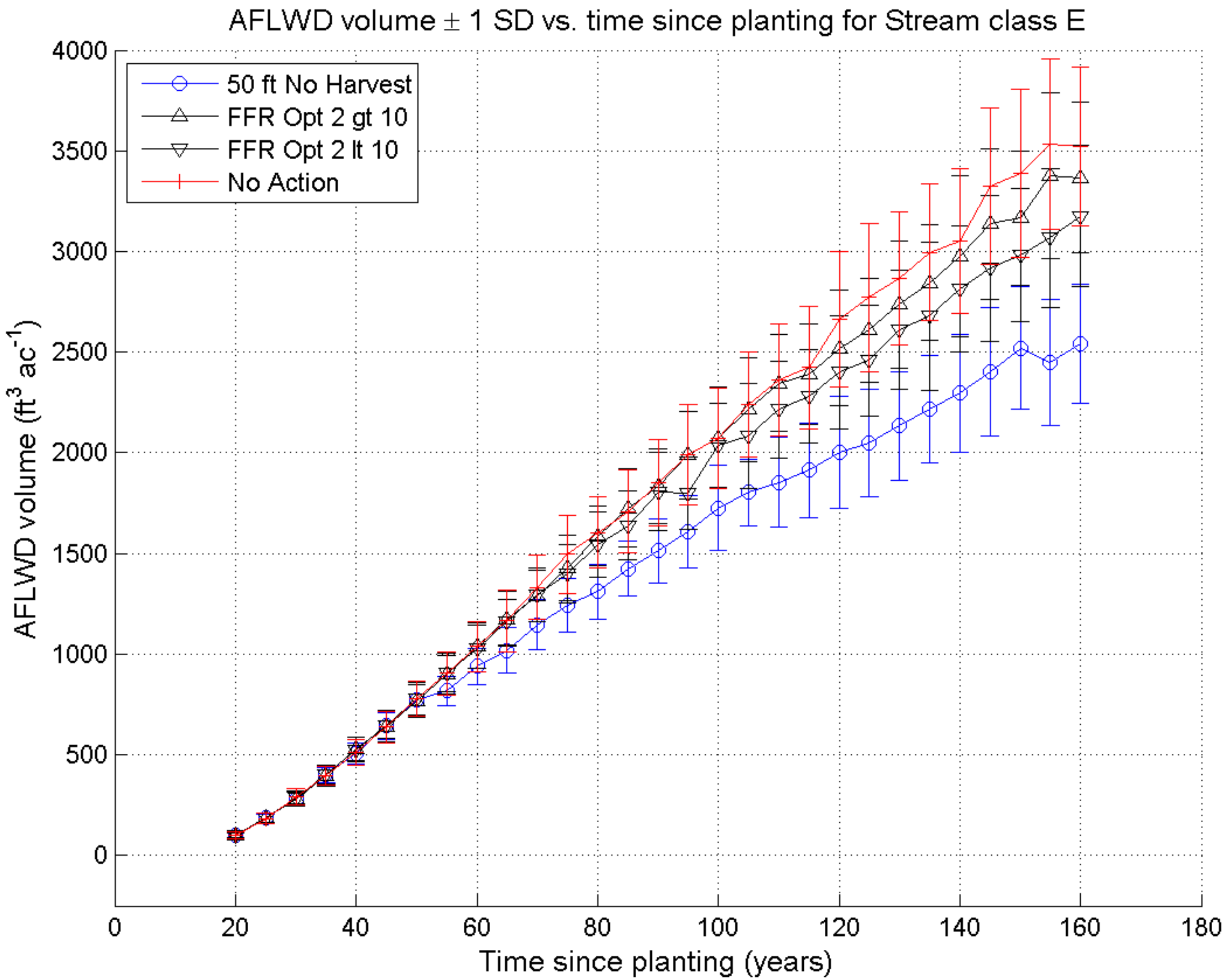


Average height ± 1 SD vs. time since planting
50 ft No Harvest
FFR Opt 2 gt 10
FFR Opt 2 lt 10
No Action
Average height (ft)
Time since planting (years)
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
160
180



BA ± 1 SD vs. time since planting
BA (ft² ac⁻¹)
Time since planting (years)
50 ft No Harvest
FFR Opt 2 gt 10
FFR Opt 2 lt 10
No Action
400
350
300
250
200
150
100
50
0
20
40
60
80
100
120
140
160
180


AFLWD pieces ± 1 SD vs. time since planting for Stream class E
AFLWD pieces (n ac-1)
Time since planting (years)
50 ft No Harvest
FFR Opt 2 gt 10
FFR Opt 2 lt 10
No Action
0
5
10
15
20
25
30
35
40
45
50
55
0
20
40
60
80
100
120
140
160
180



AFLWD volume ± 1 SD vs. time since planting for Stream class E
50 ft No Harvest
FFR Opt 2 gt 10
FFR Opt 2 lt 10
No Action
AFLWD volume (ft^3 ac^{-1})
Time since planting (years)
0
500
1000
1500
2000
2500
3000
3500
4000
0
20
40
60
80
100
120
140
160
180

Shade Model Steps

- Step 1: Choose tree list data
- Step 2: Choose a representation for the stand, e.g., slabs of uniform properties or individual tree slabs
- Step 3: Choose a stream width
- Step 4: Choose light transmission factors for different canopy and/or tree elements being modeled

Shade Model Steps (cont)

- Step 5: Generate the uniform slabs or individual tree slabs for a selected tree list
- Step 6: Generate a riparian stand by replicating the slabs four times, two on each side of the stream
  - Different tree lists could be used if desired

Shade Model Steps (cont)

- Step 7: Integrate the light reception on a unit hemisphere located at the center of the stream and the four replicated stands
  - Generate uniformly distributed points on the surface of the hemisphere
  - Project rays from the center point through the surface points
  - Find intersections with the slabs or tree slabs to determine light hitting the hemisphere

Shade Model Steps (cont)

- Step 8: Compute the ratio of integrated light transmission with and without the forest slabs (with/without)
  - This provides a relative blocking factor that is independent of sun position and stream orientation.
- Step 9: Repeat steps 1-8 in a bootstrap simulation for each stand or tree list to obtain estimates of variability

Shade Model Steps (cont)

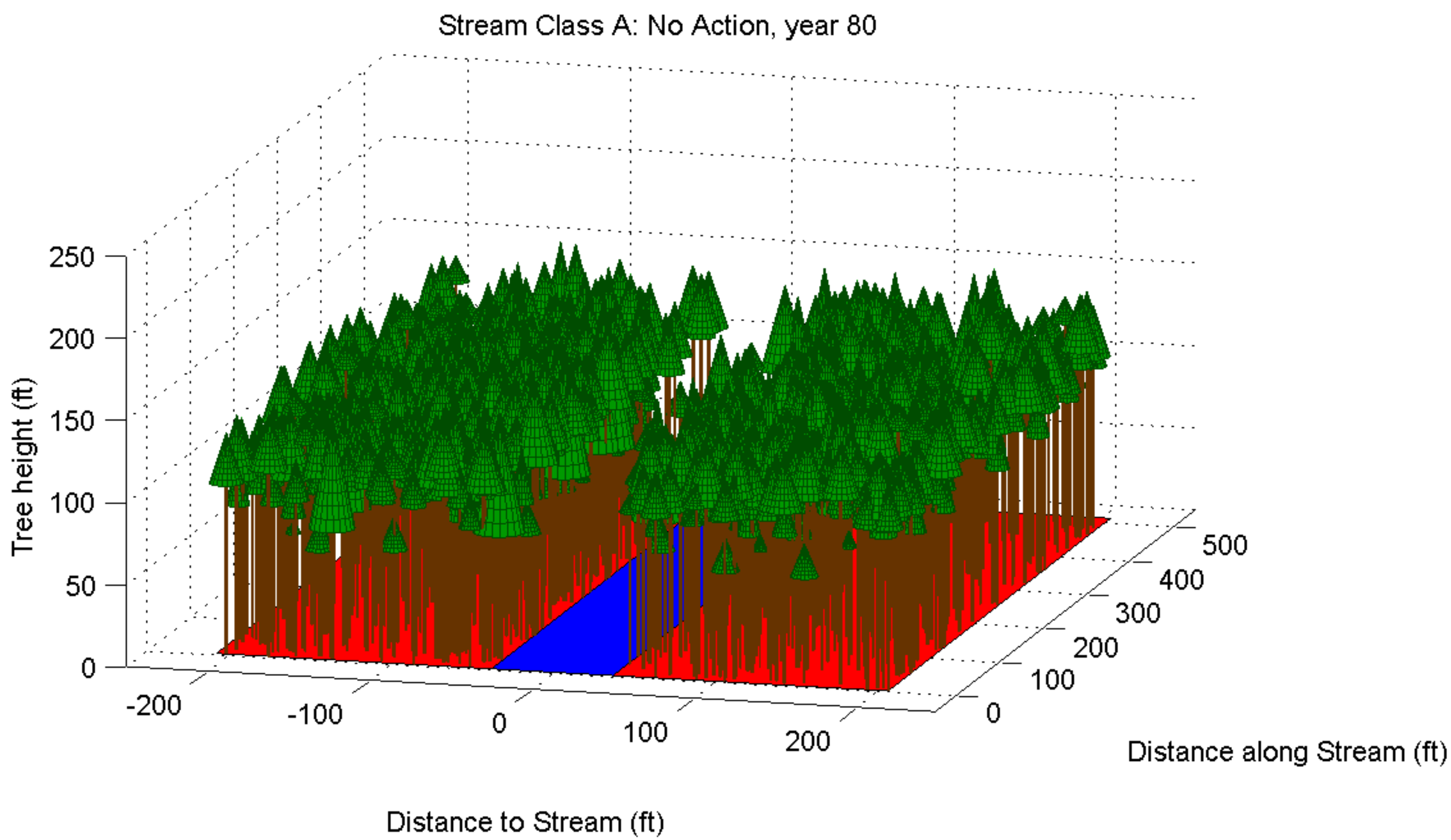
- Assumptions
  - Energy input follows a sinusoidal decay from the zenith to the horizon
  - Light transmission through each slab is independent
    - No “darkening” for overlapping crowns
    - First bole slab hit reduces transmission to zero
  - This is essentially the RAIS model for the uniform slabs, and a refinement for tree slabs
  - Transmissivity values from RAIS

Shade Simulation Example

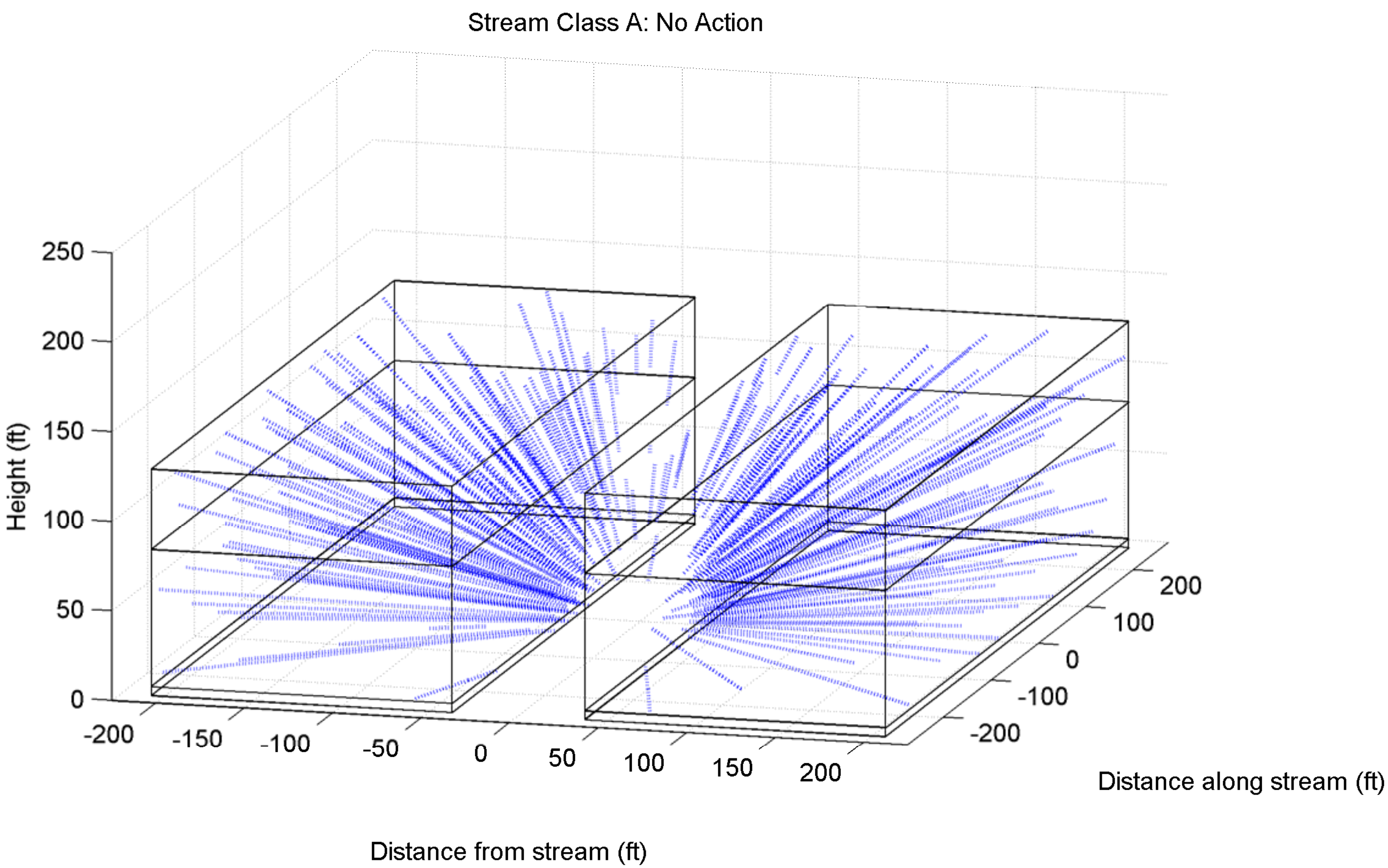
- Four treatments for a 170 foot wide 256.2 foot long 1 acre buffer zone at age 80
  - 170 foot no action
  - 50 foot no harvest buffer with 50 year rotation from 50 to 170 feet
  - FFR option 2 for stream BFW < 10 feet
  - FFR option 2 for stream BFW> 10 feet
    - For the FFR options, trees were randomly located post harvest, not closer to the stream

Uniform Slabs

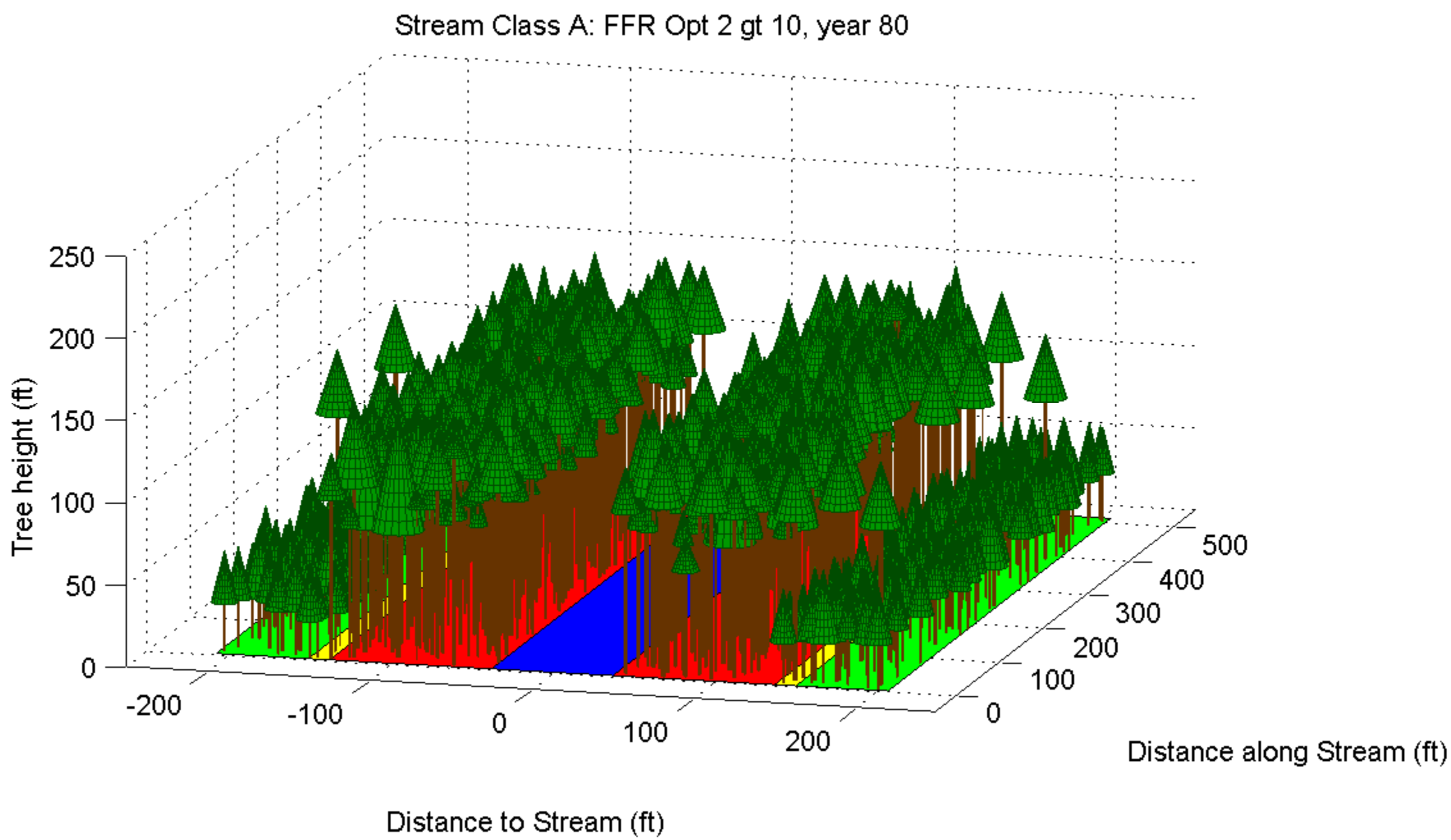
- Canopy transmissivity 0.95 per foot
- Under canopy transmissivity 0.99 per foot
- Shrub transmissivity 0.84 per foot
- Shrub height 5 feet
  - Included if lower canopy height > 10 ft
- Upper canopy height = mean tree height
- Lower canopy height = mean of minimum crown base height and median crown base height



Stream Class A: No Action, year 80
Tree height (ft)
250
200
150
100
50
0
-200
-100
0
100
200
Distance to Stream (ft)
500
400
300
200
100
0
Distance along Stream (ft)

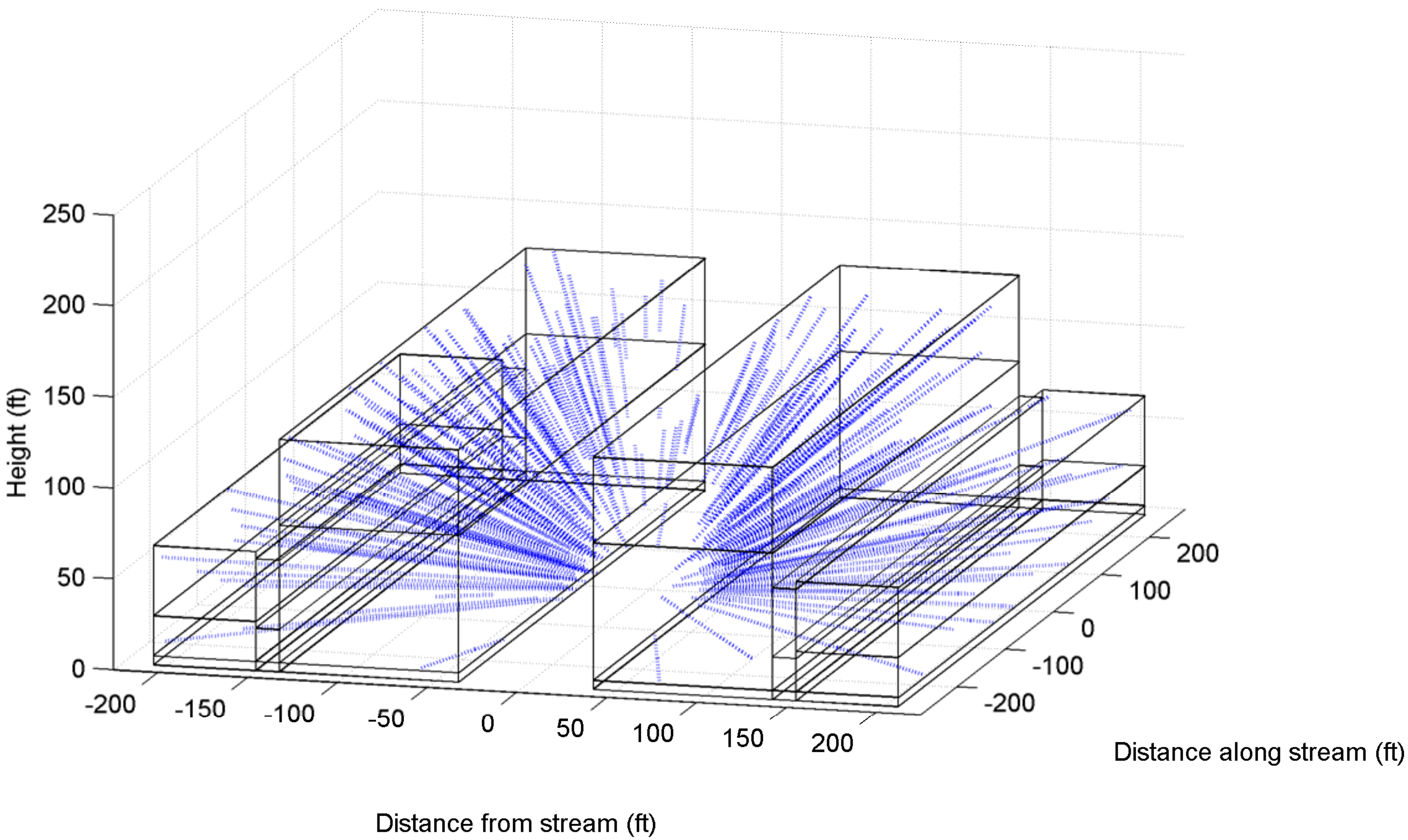


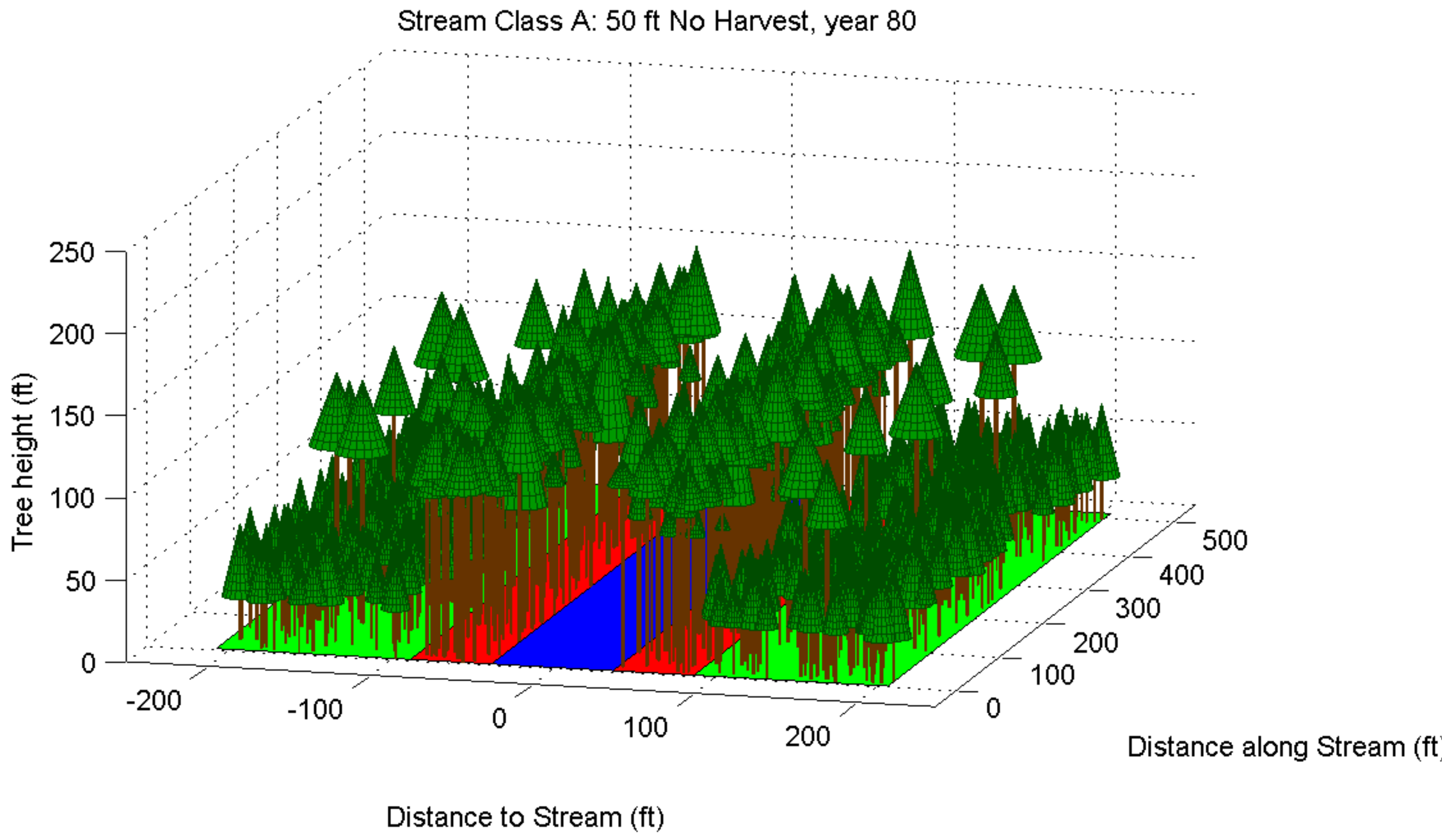
Stream Class A: No Action
Height (ft)
250
200
150
100
50
0
-200
-150
-100
-50
0
50
100
150
200
Distance from stream (ft)
200
100
0
-100
-200
Distance along stream (ft)



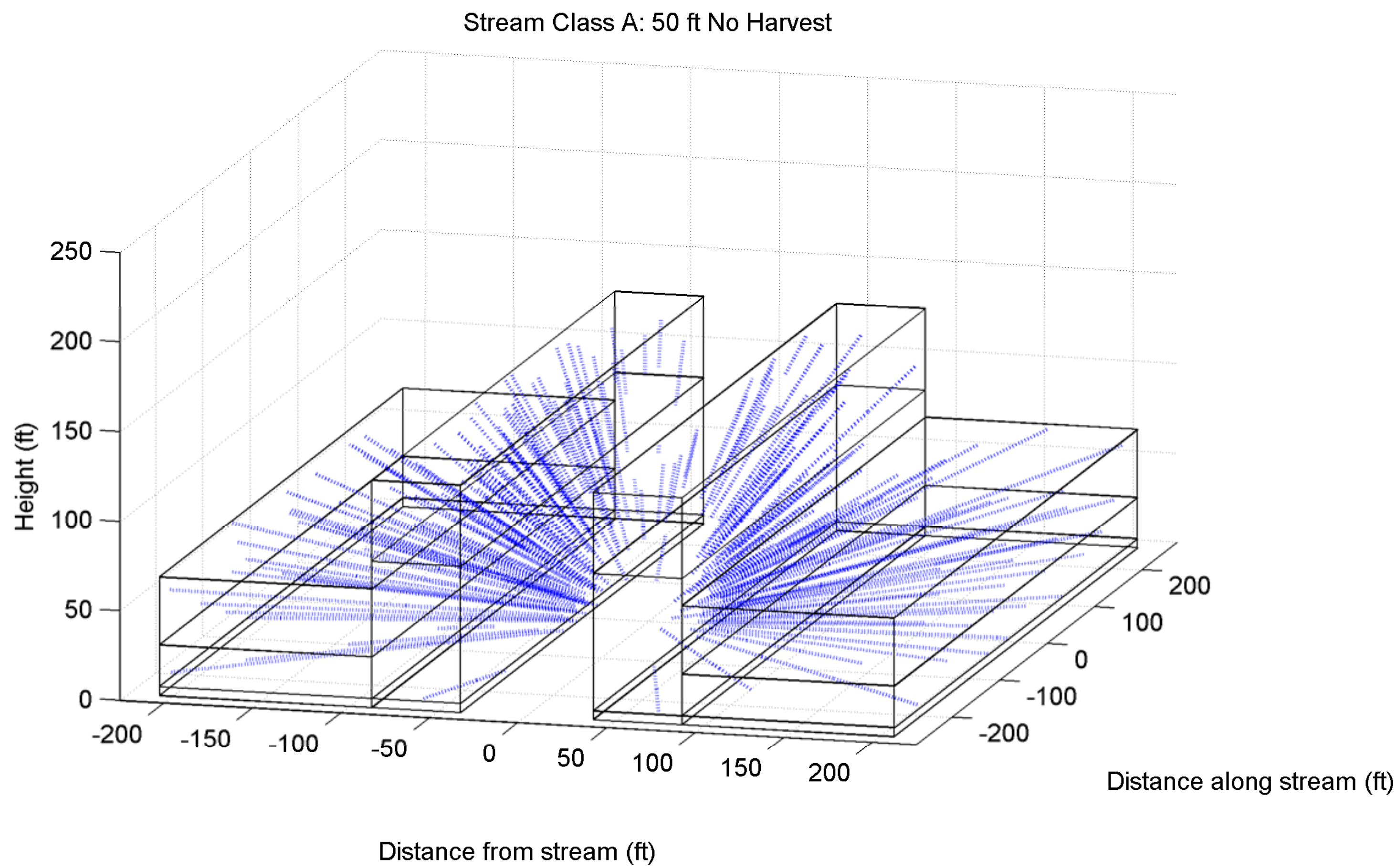
Stream Class A: FFR Opt 2 gt 10, year 80
Tree height (ft)
250
200
150
100
50
0
-200
-100
0
100
200
Distance to Stream (ft)
0
100
200
300
400
500
Distance along Stream (ft)

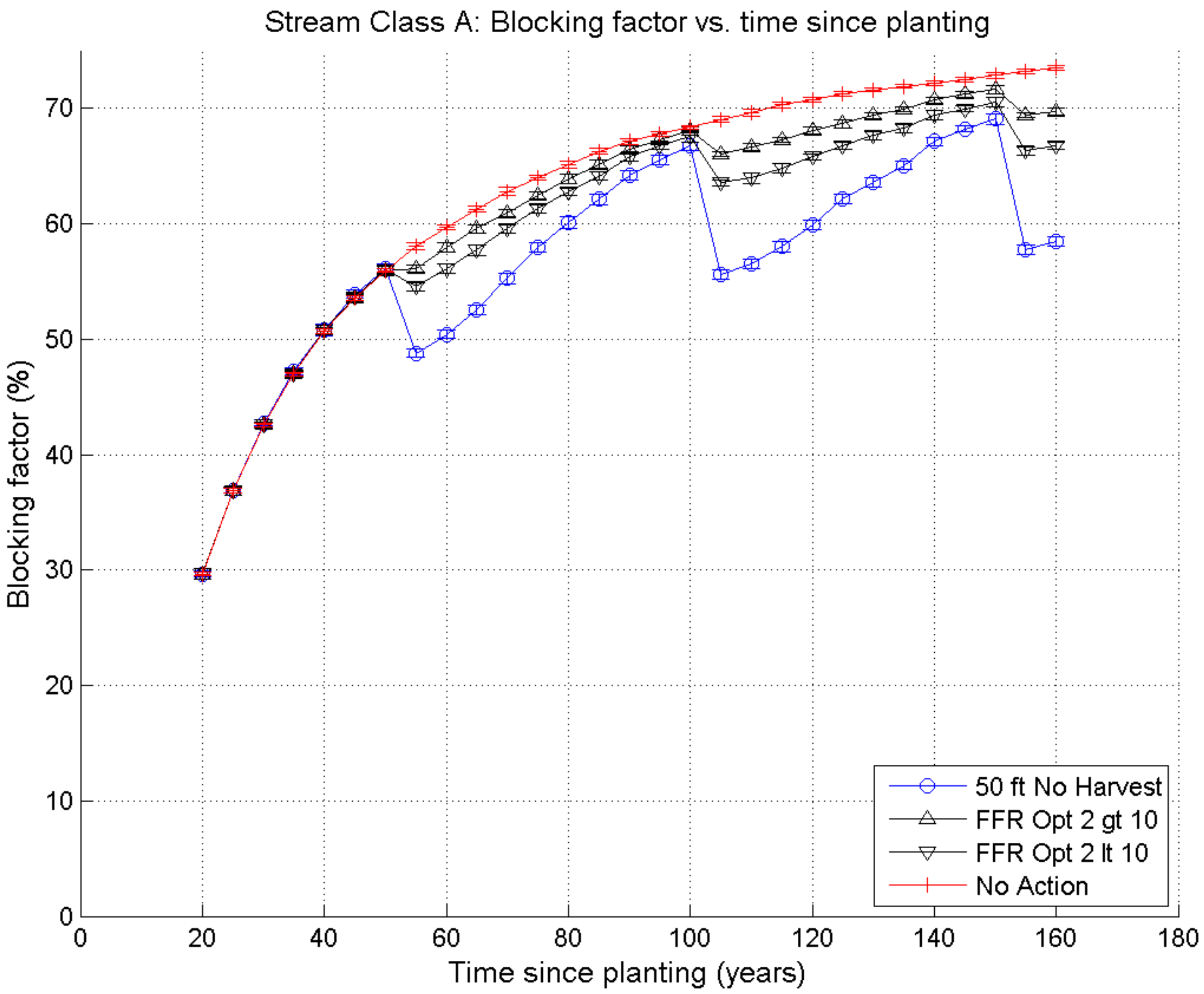
Stream Class A: FFR Opt 2 gt 10



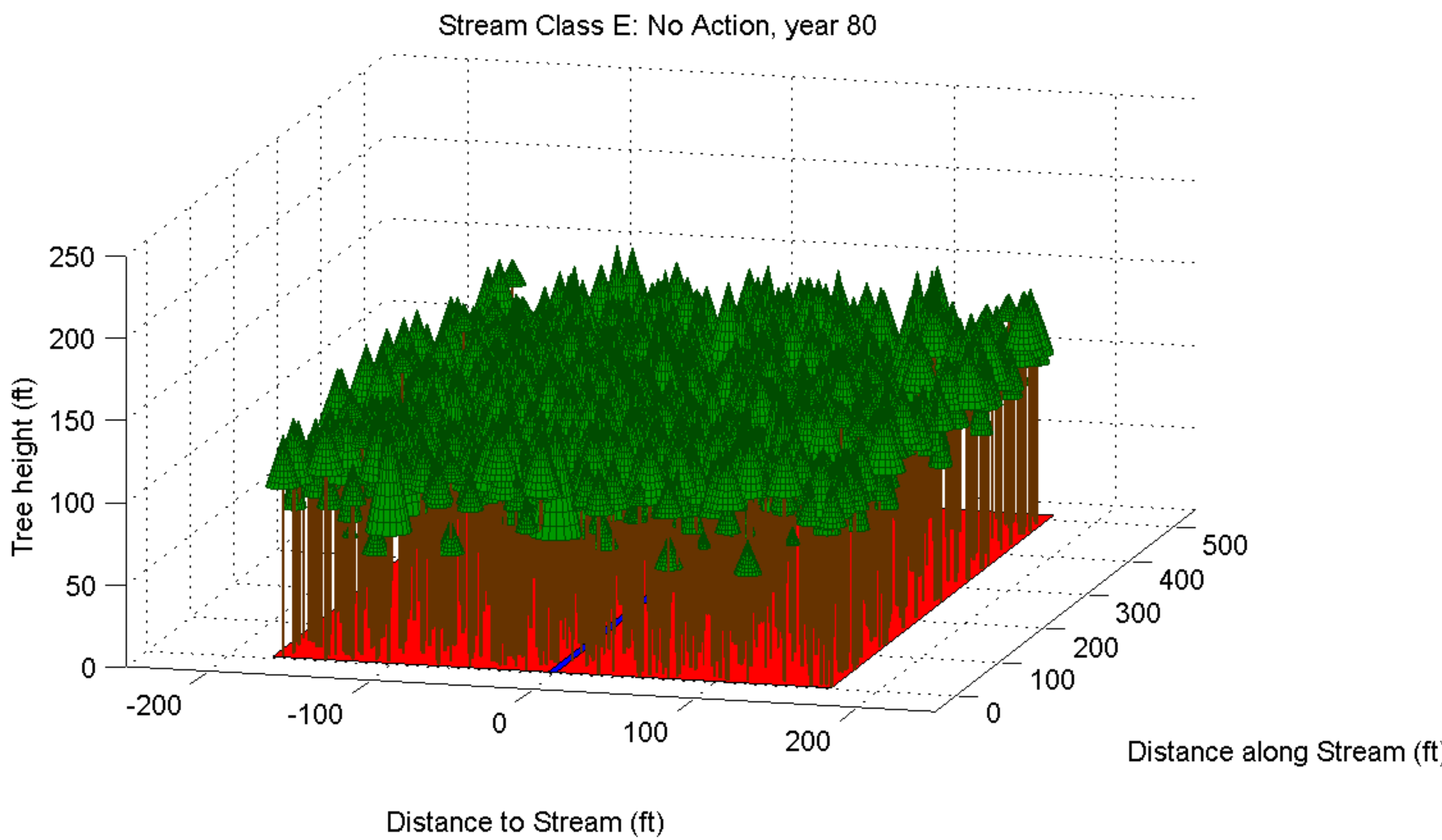


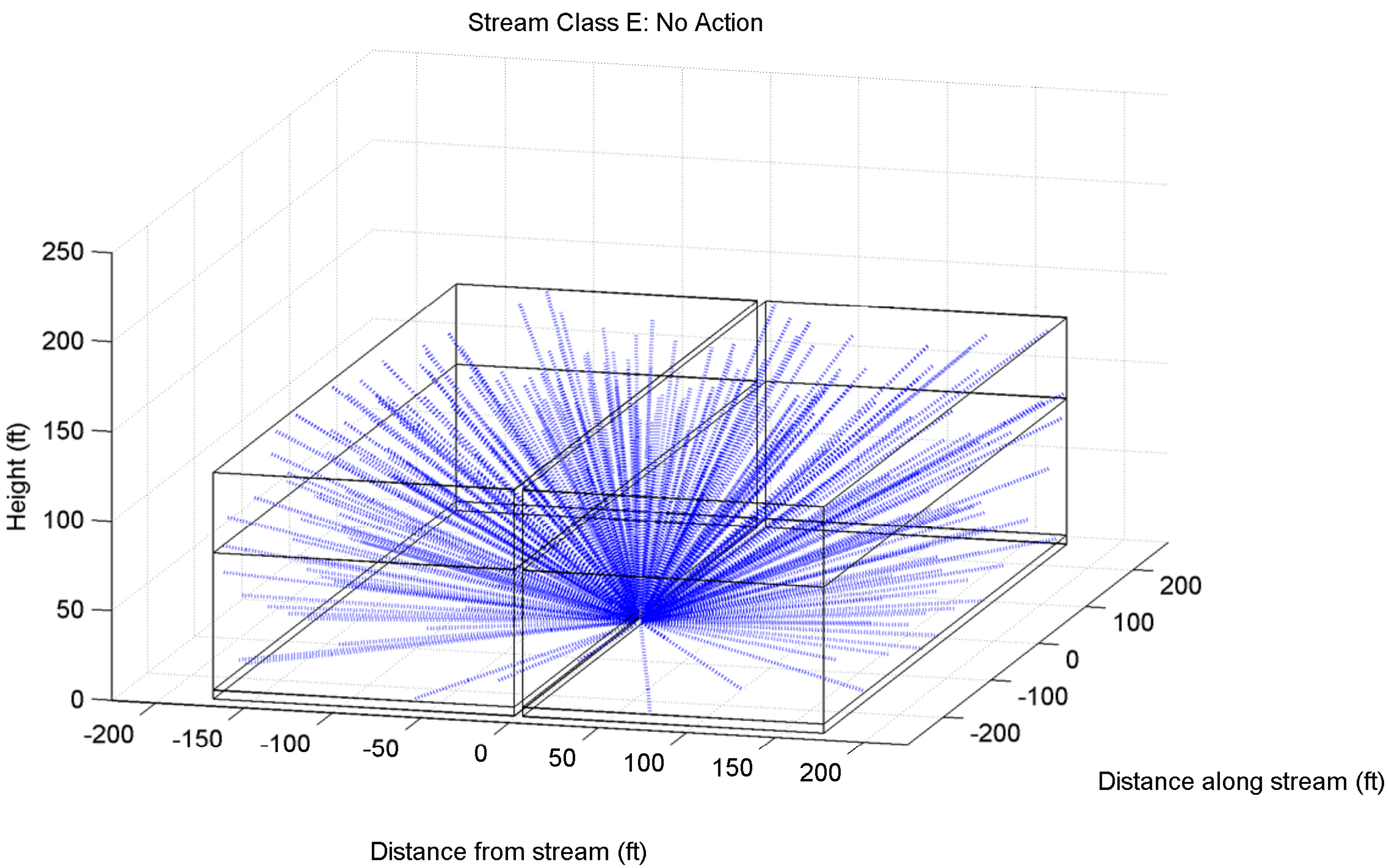
Stream Class A: 50 ft No Harvest, year 80
Tree height (ft)
250
200
150
100
50
0
-200
-100
0
100
200
Distance to Stream (ft)
0
100
200
300
400
500
Distance along Stream (ft)


Stream Class A: 50 ft No Harvest
Height (ft)
250
200
150
100
50
0
-200
-150
-100
-50
0
50
100
150
200
Distance from stream (ft)
200
100
0
-100
-200
Distance along stream (ft)

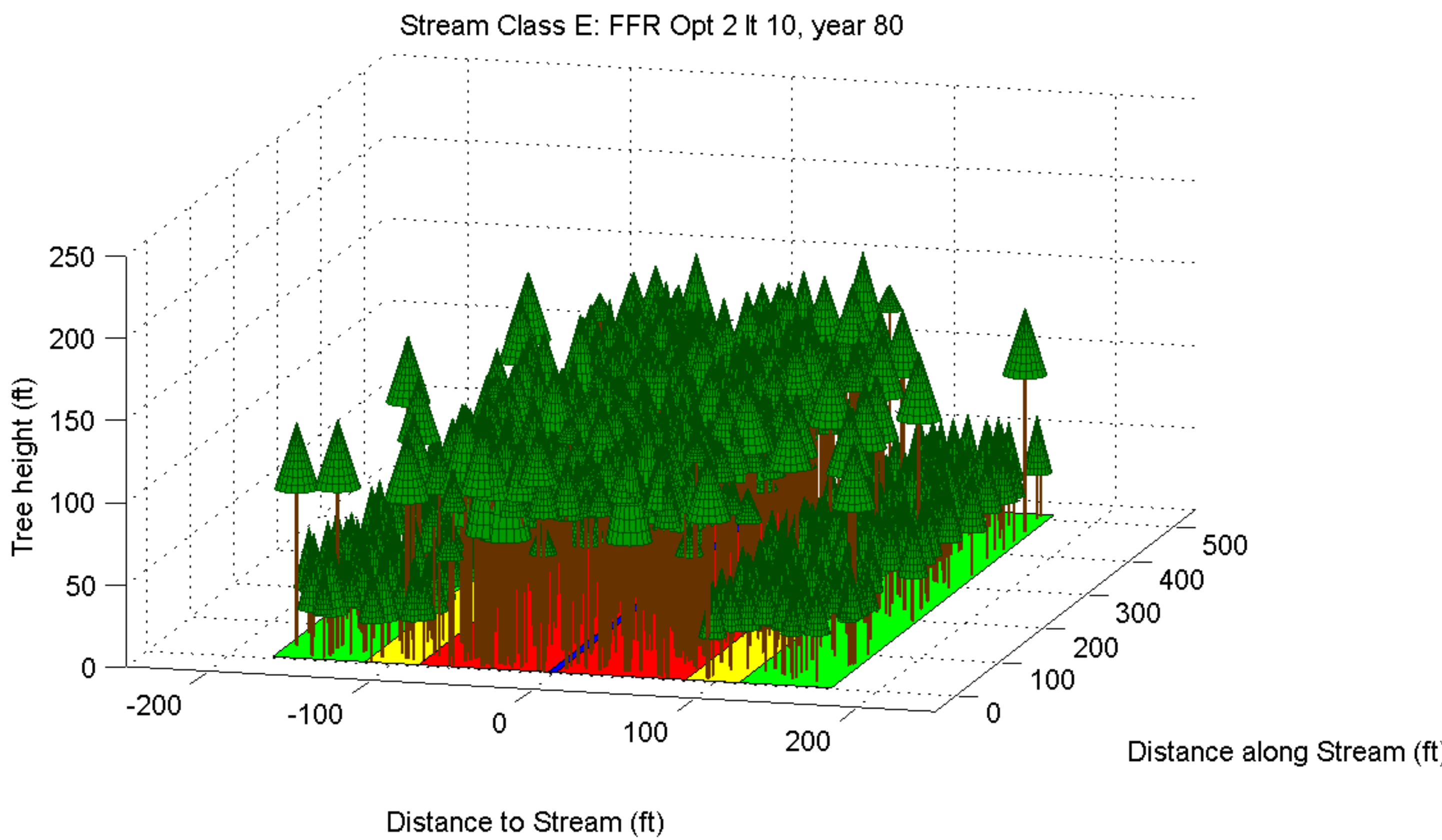


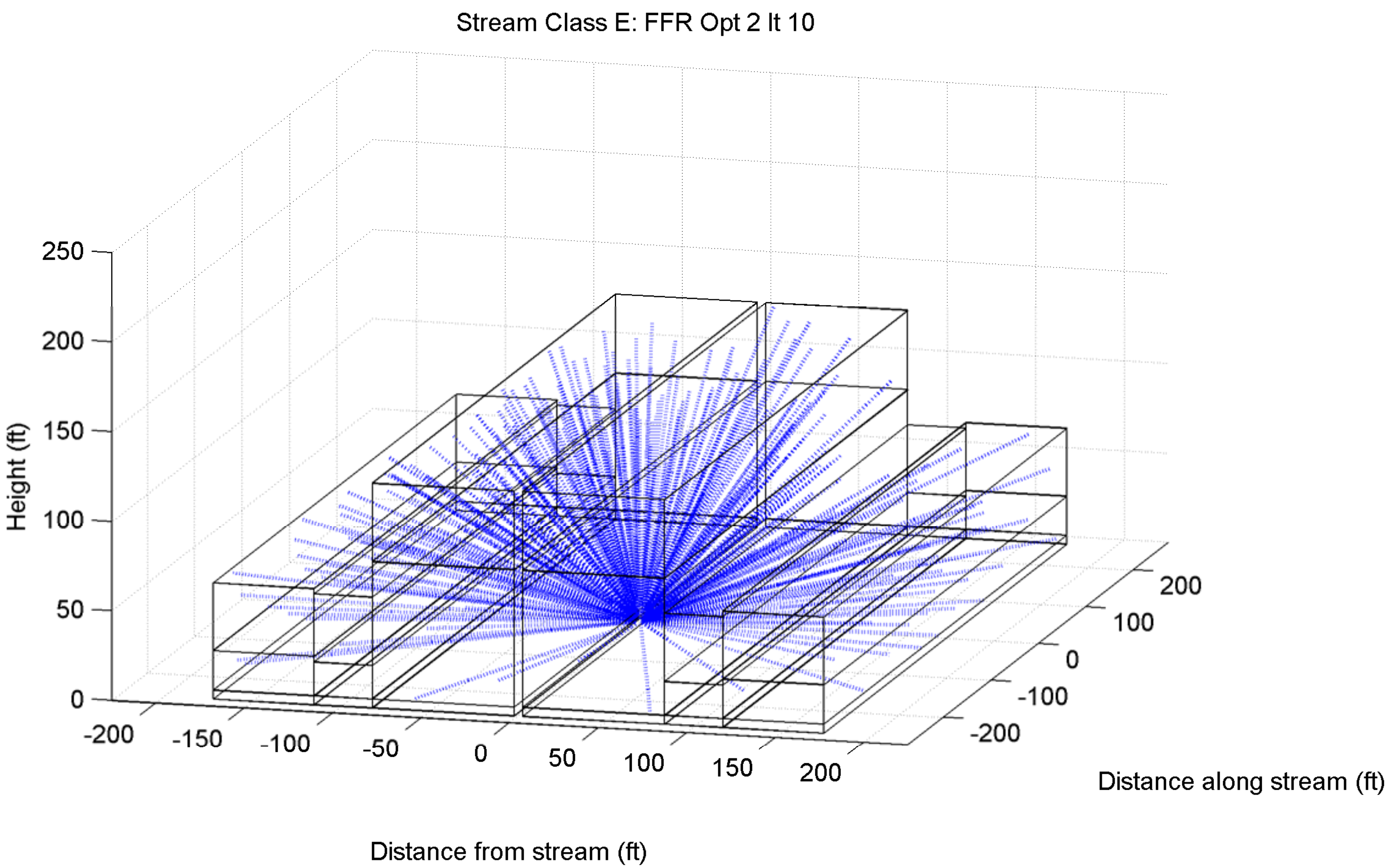
Stream Class A: Blocking factor vs. time since planting
Blocking factor (%)
Time since planting (years)
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
140
160
180
50 ft No Harvest
FFR Opt 2 gt 10
FFR Opt 2 lt 10
No Action


Stream Class E: No Action, year 80
Tree height (ft)
250
200
150
100
50
0
-200
-100
0
100
200
Distance to Stream (ft)
0
100
200
300
400
500
Distance along Stream (ft)

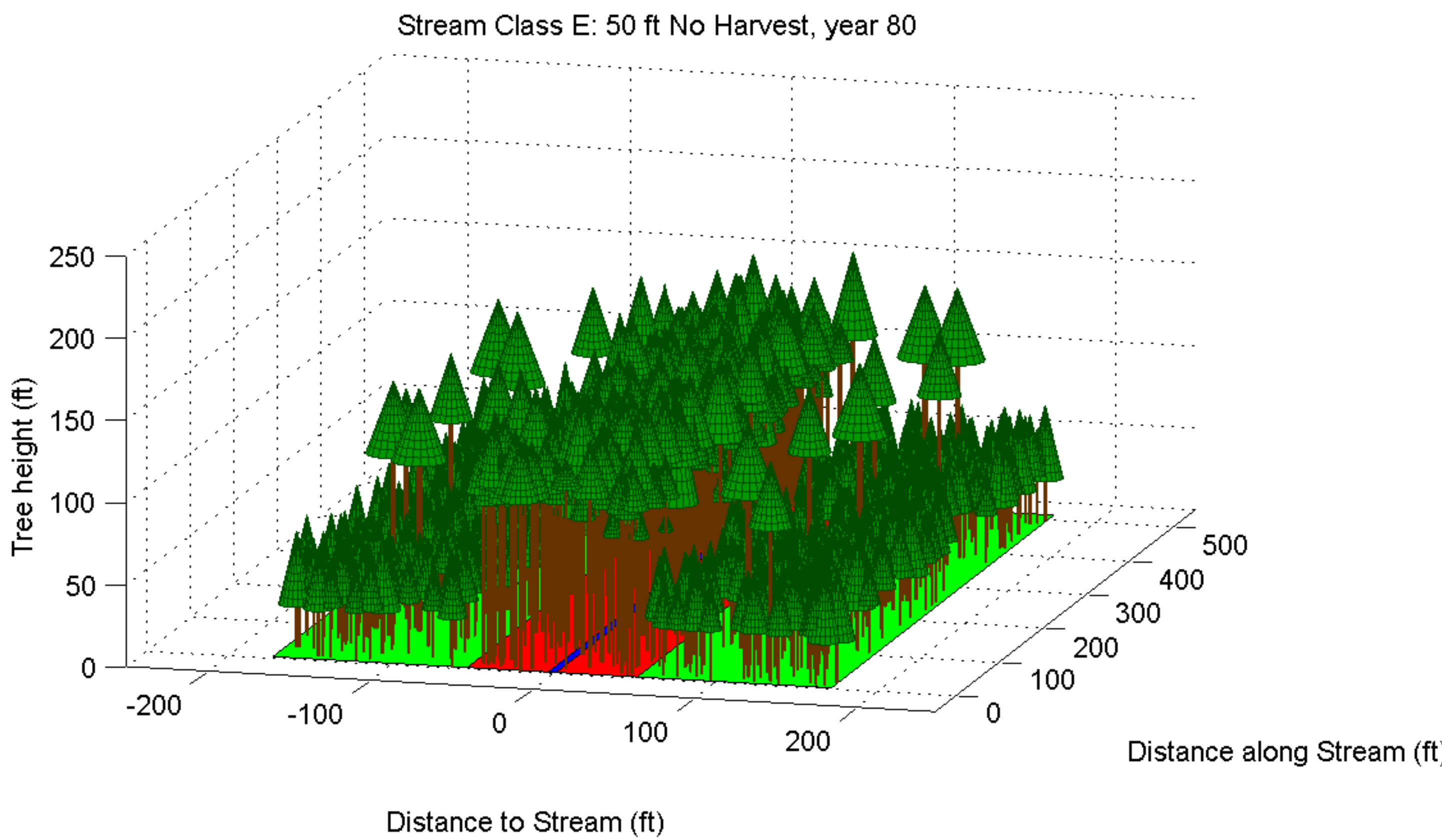


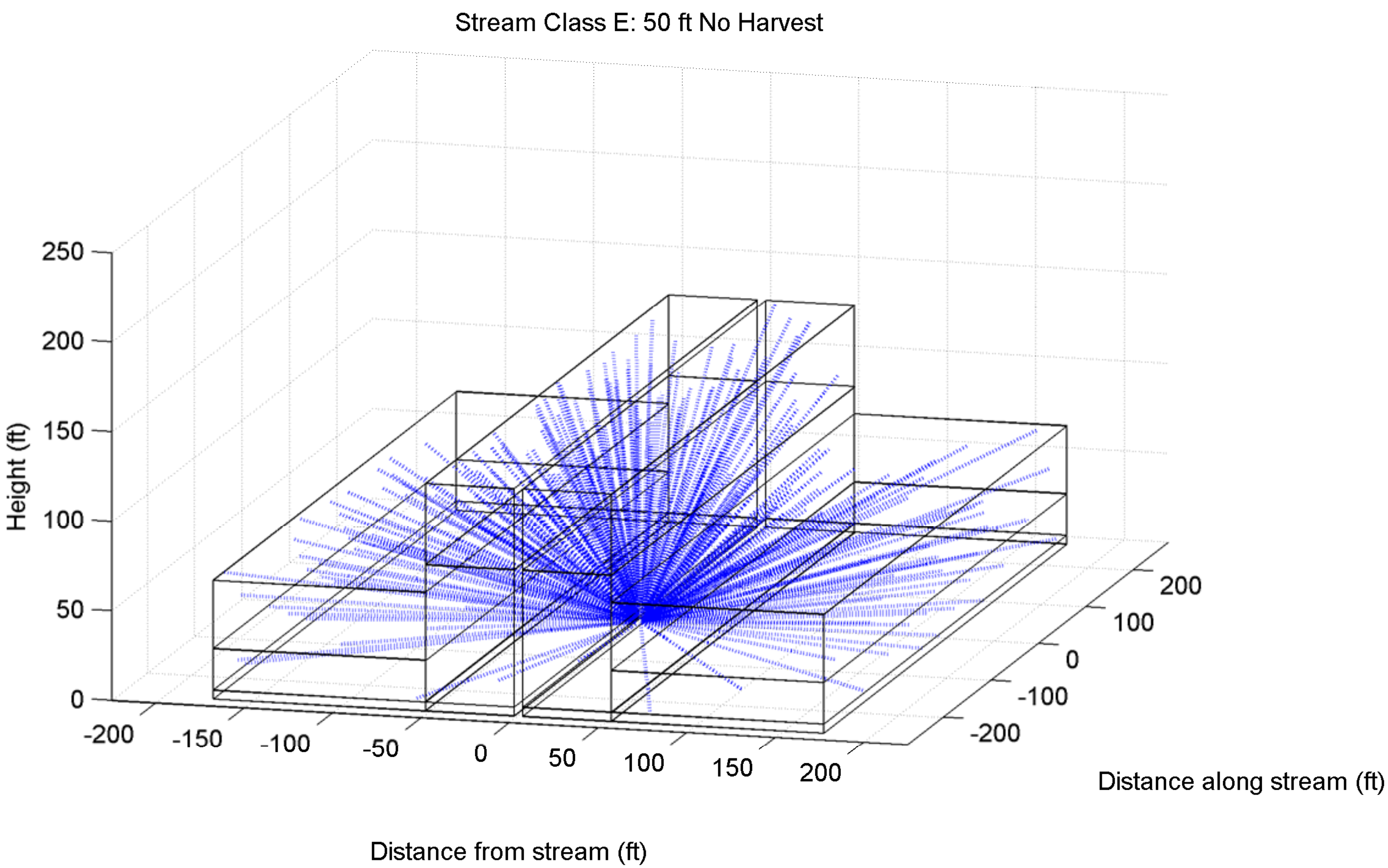
Stream Class E: No Action
Height (ft)
250
200
150
100
50
0
-200
-150
-100
-50
0
50
100
150
200
Distance from stream (ft)
200
100
0
-100
-200
Distance along stream (ft)


Stream Class E: FFR Opt 2 It 10, year 80
Tree height (ft)
250
200
150
100
50
0
-200
-100
0
100
200
Distance to Stream (ft)
0
100
200
300
400
500
Distance along Stream (ft)

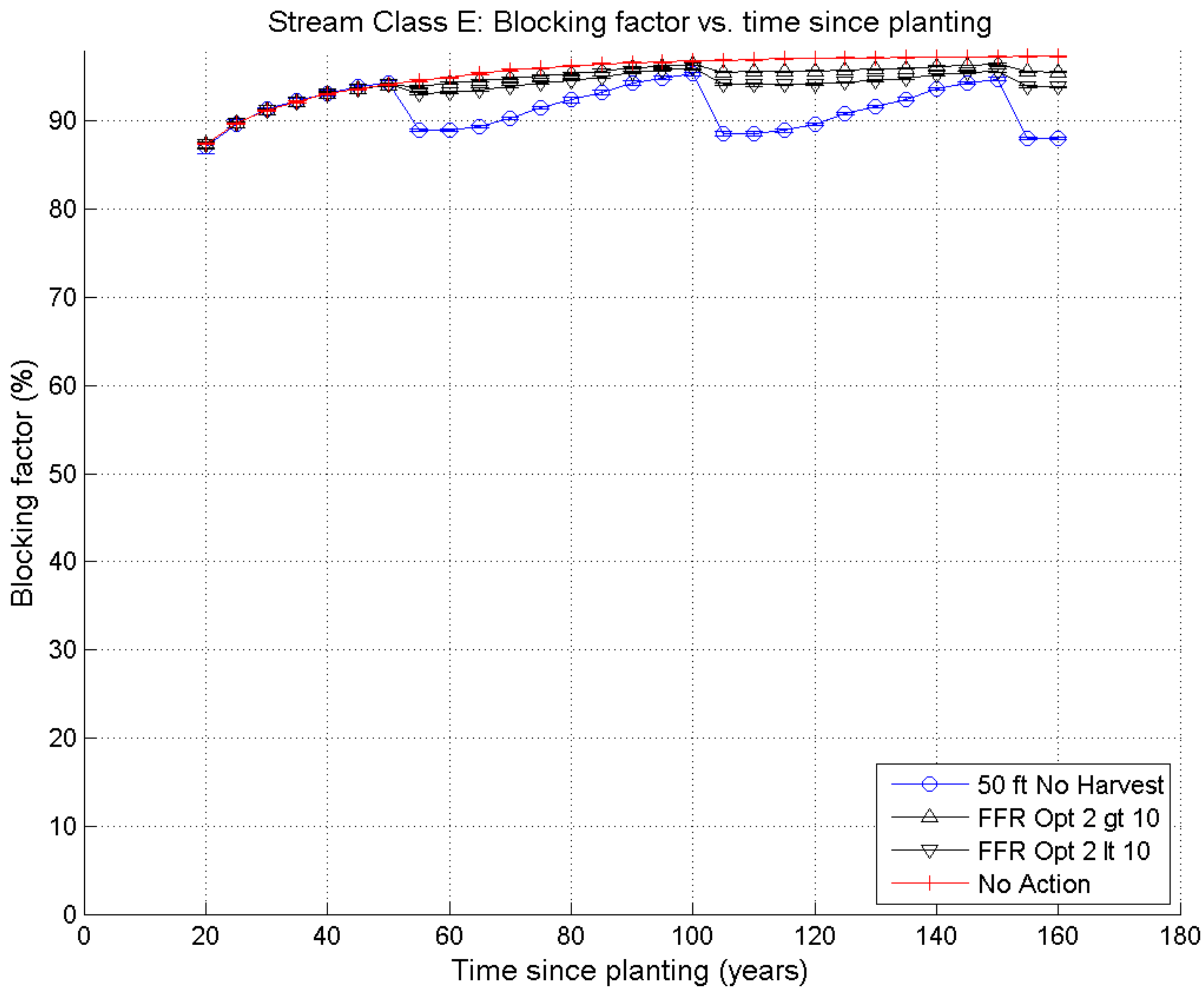


Stream Class E: FFR Opt 2 It 10
Height (ft)
250
200
150
100
50
0
-200
-150
-100
-50
0
50
100
150
200
Distance from stream (ft)
200
100
0
-100
-200
Distance along stream (ft)


Stream Class E: 50 ft No Harvest, year 80
Tree height (ft)
250
200
150
100
50
0
-200
-100
0
100
200
Distance to Stream (ft)
0
100
200
300
400
500
Distance along Stream (ft)



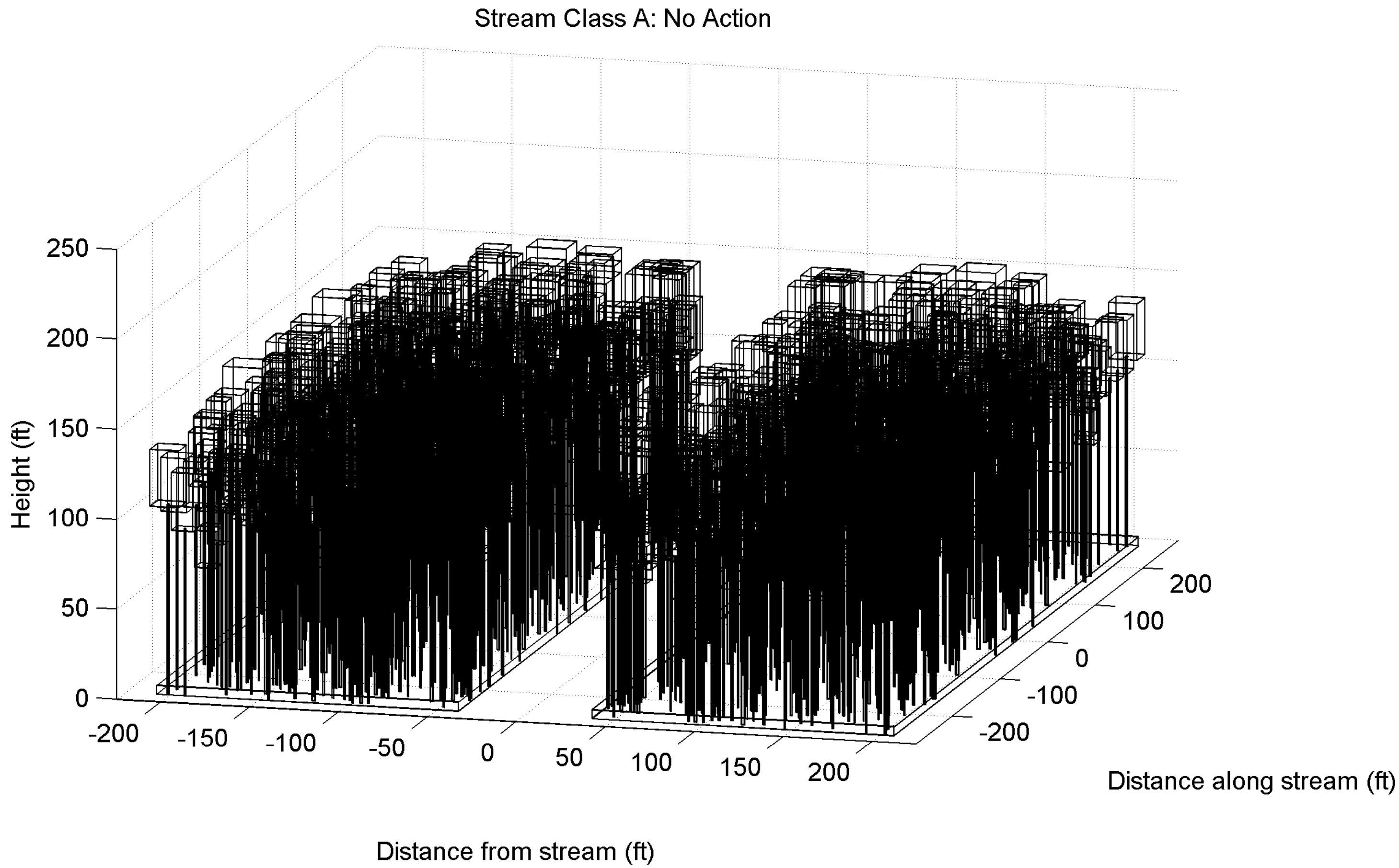
Stream Class E: 50 ft No Harvest
Height (ft)
250
200
150
100
50
0
-200
-150
-100
-50
0
50
100
150
200
Distance from stream (ft)
200
100
0
-100
-200
Distance along stream (ft)



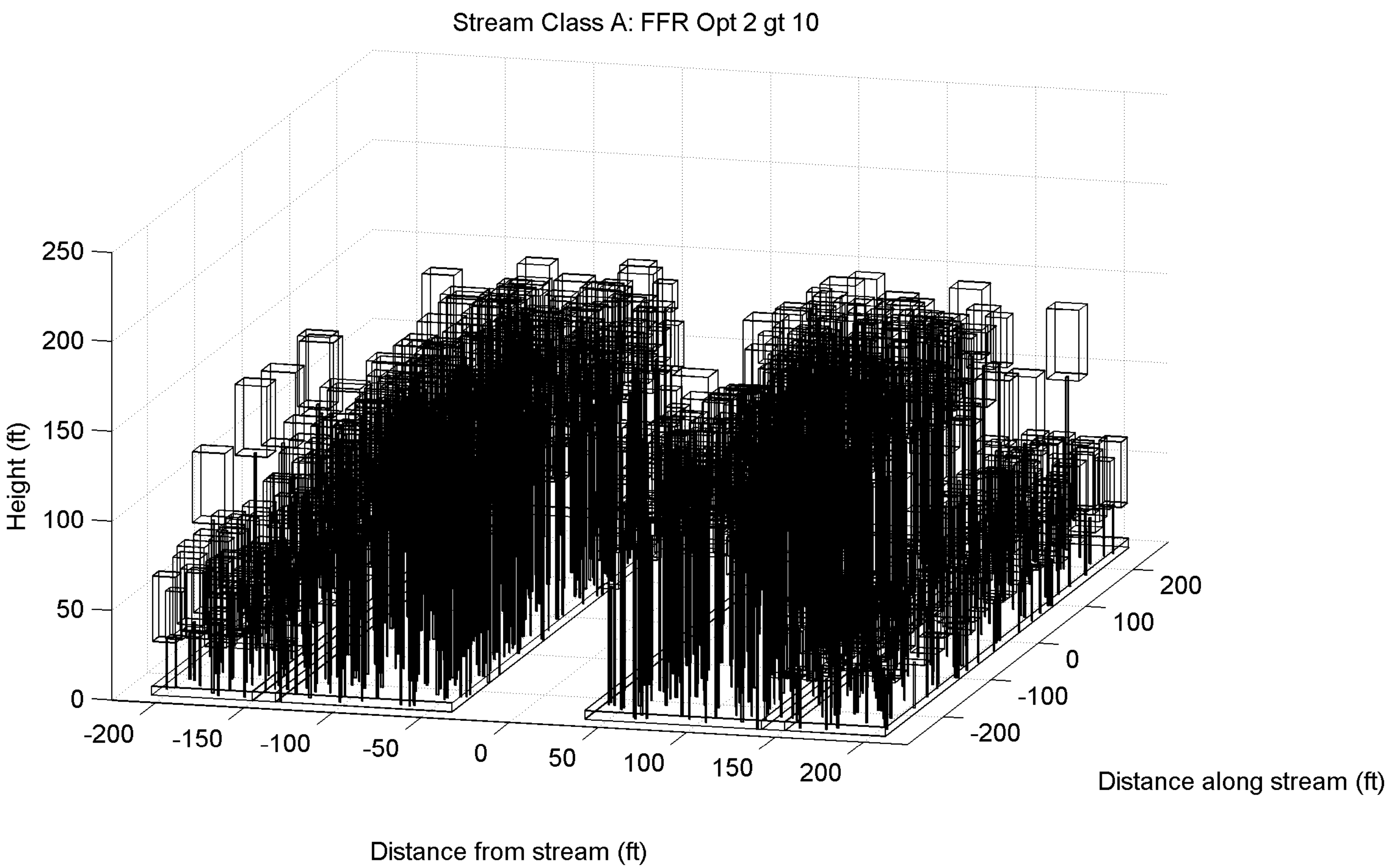
Stream Class E: Blocking factor vs. time since planting
Blocking factor (%)
Time since planting (years)
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
160
180
50 ft No Harvest
FFR Opt 2 gt 10
FFR Opt 2 lt 10
No Action

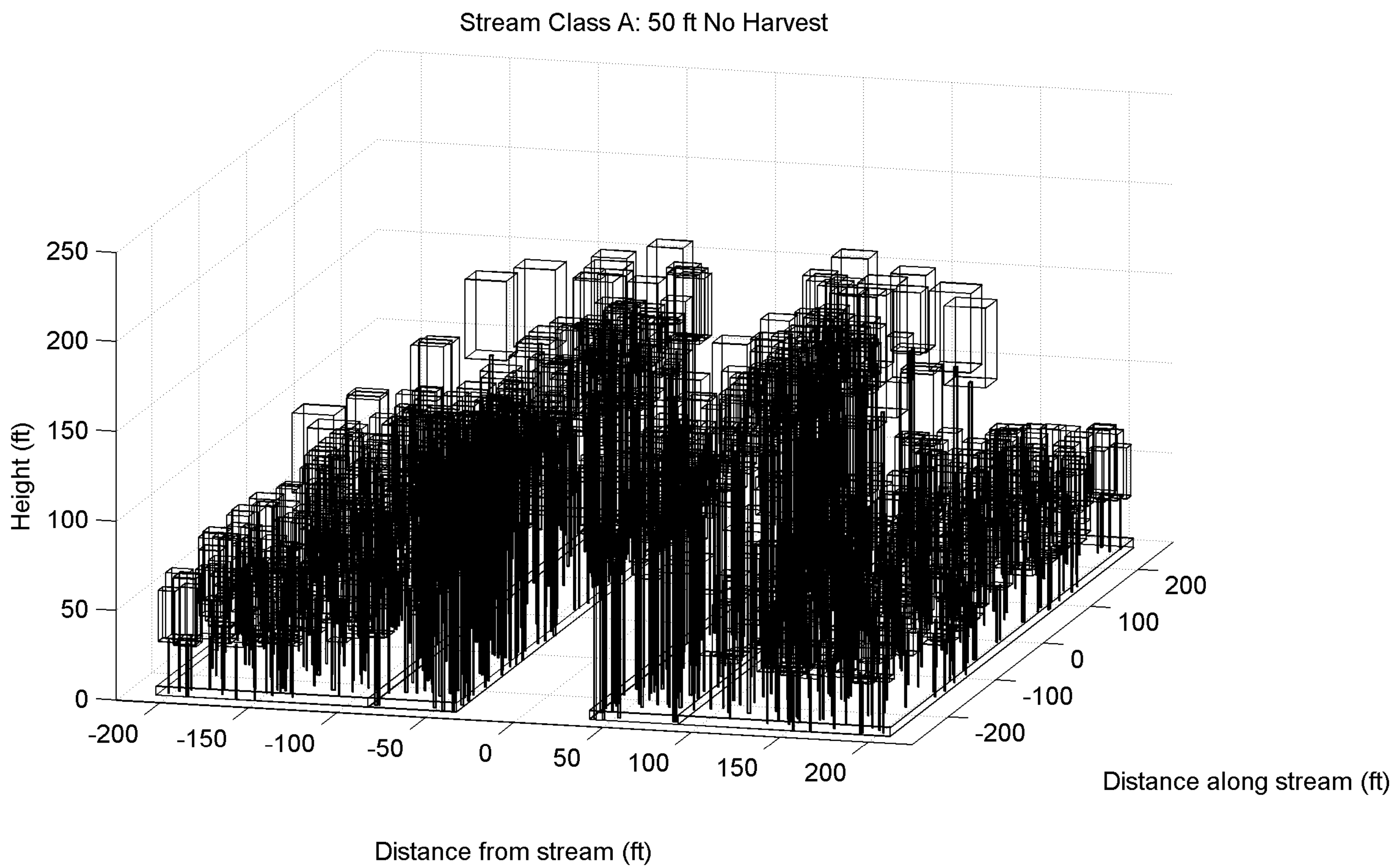
Individual tree slabs

- Tree crown transmissivity 0.95 per foot
- Tree bole transmissivity 0.00 per foot
- Shrub transmissivity 0.84 per foot
- Shrub height 5 feet (if lower canopy height > 10 ft)
- Crown and bole modeled as boxes
  - Crown: box inscribed in circle with crown base diameter, height from crown base to tree top
  - Bole: box inscribed in circle with diameter DBH, height from ground to crown base

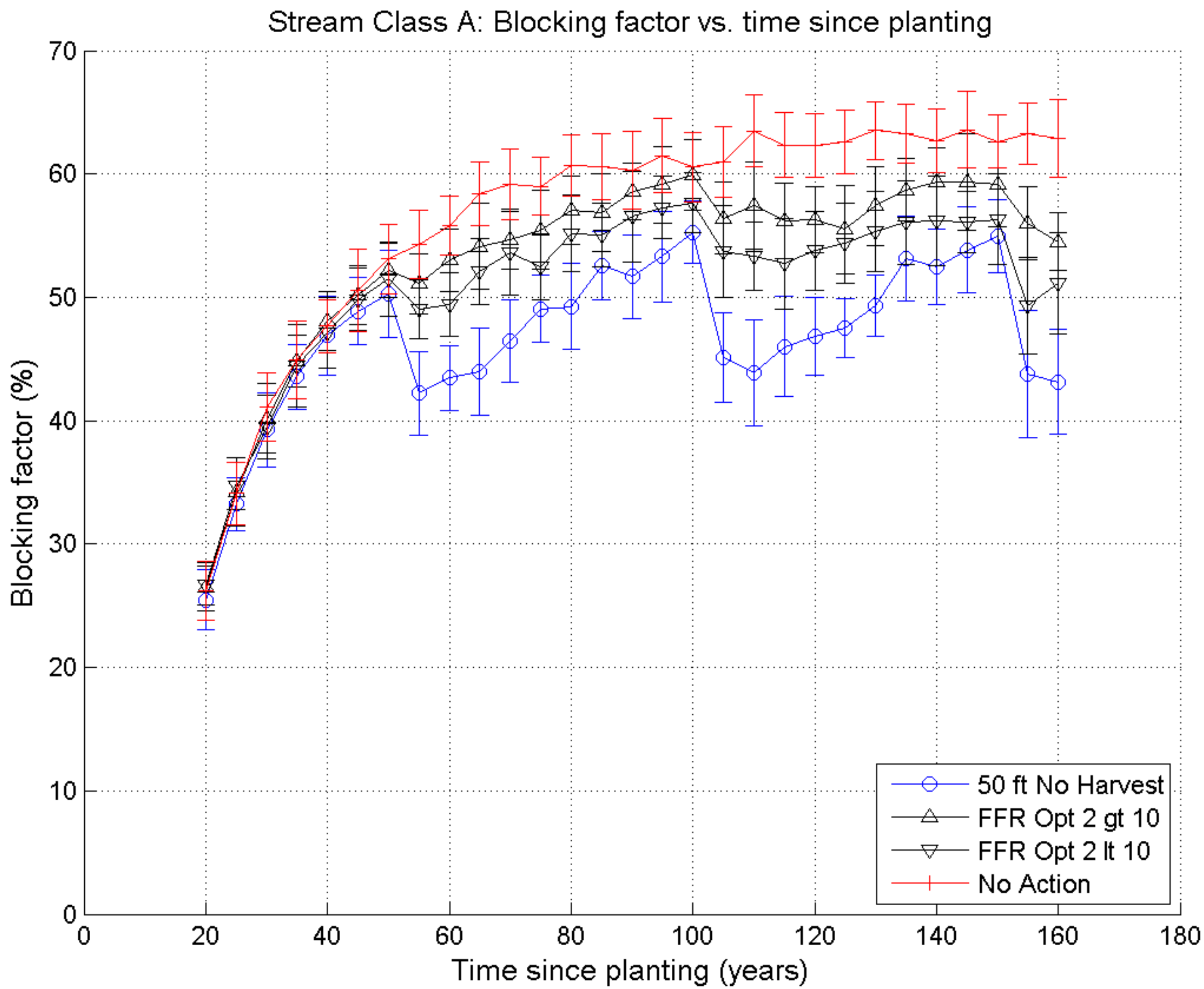


Stream Class A: No Action
Height (ft)
250
200
150
100
50
0
-200
-150
-100
-50
0
50
100
150
200
Distance from stream (ft)
200
100
0
-100
-200
Distance along stream (ft)

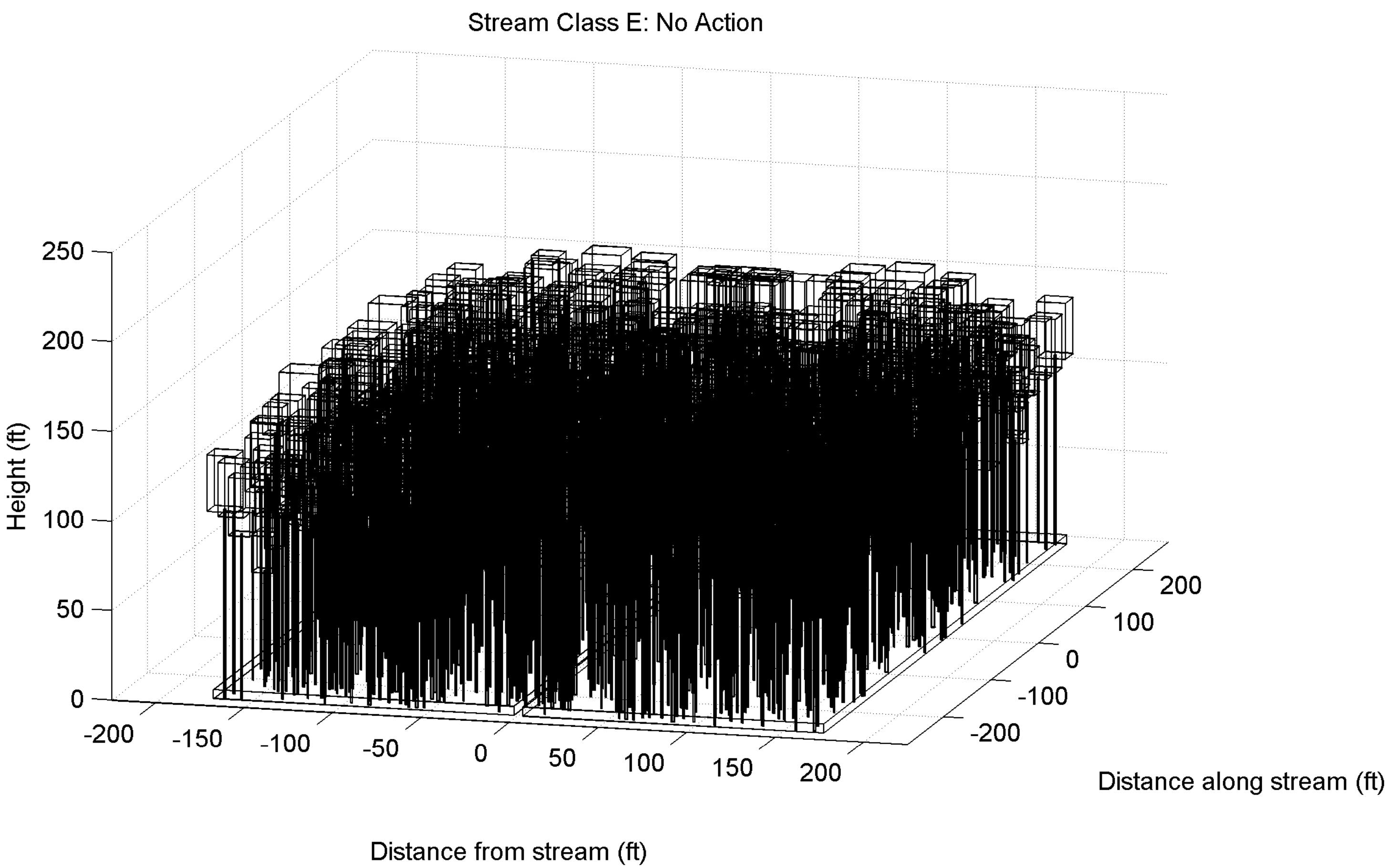

Stream Class A: FFR Opt 2 gt 10
Height (ft)
250
200
150
100
50
0
-200
-150
-100
-50
0
50
100
150
200
Distance from stream (ft)
200
100
0
-100
-200
Distance along stream (ft)

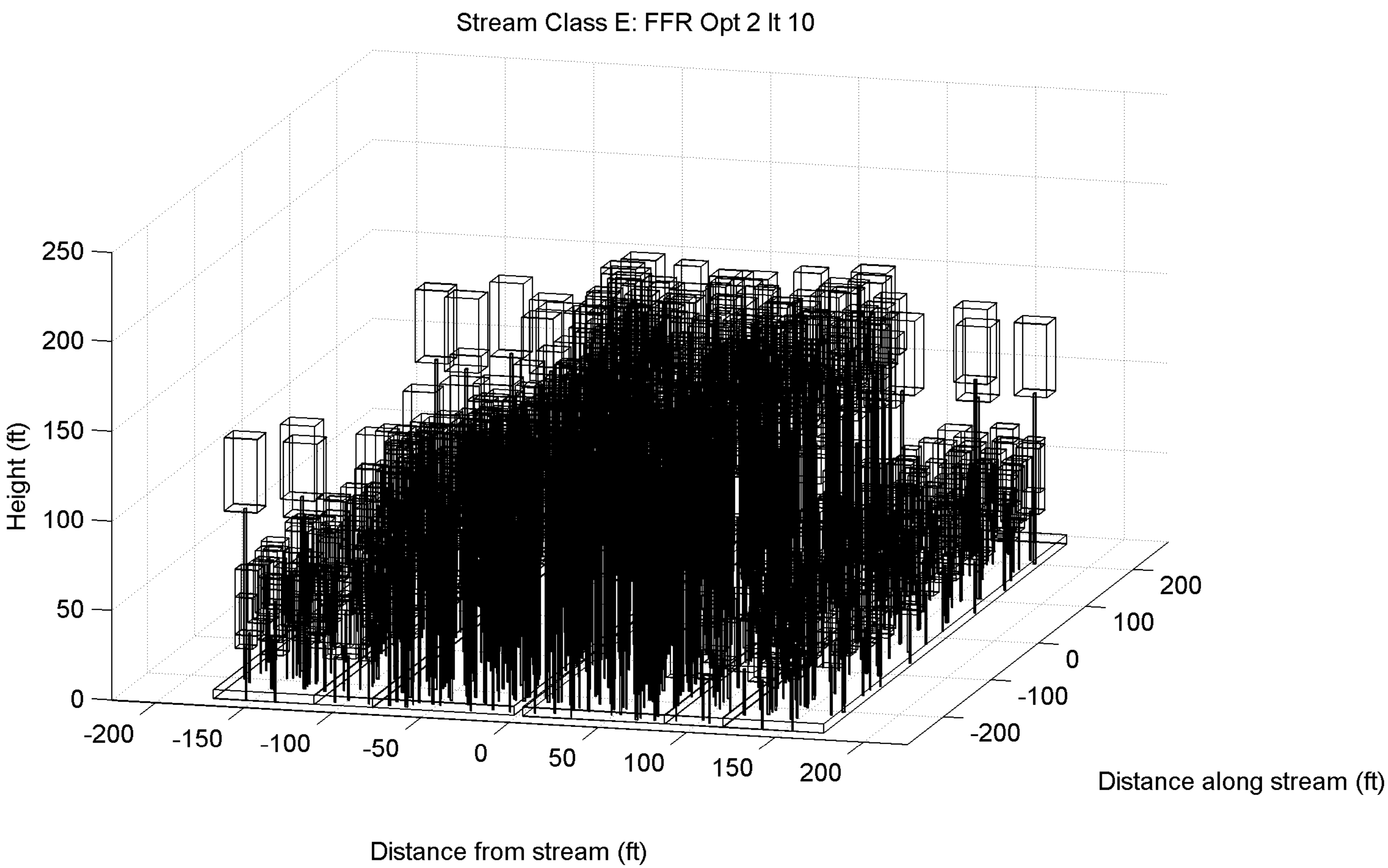


Stream Class A: 50 ft No Harvest
Height (ft)
250
200
150
100
50
0
-200
-150
-100
-50
0
50
100
150
200
Distance from stream (ft)
200
100
0
-100
-200
Distance along stream (ft)

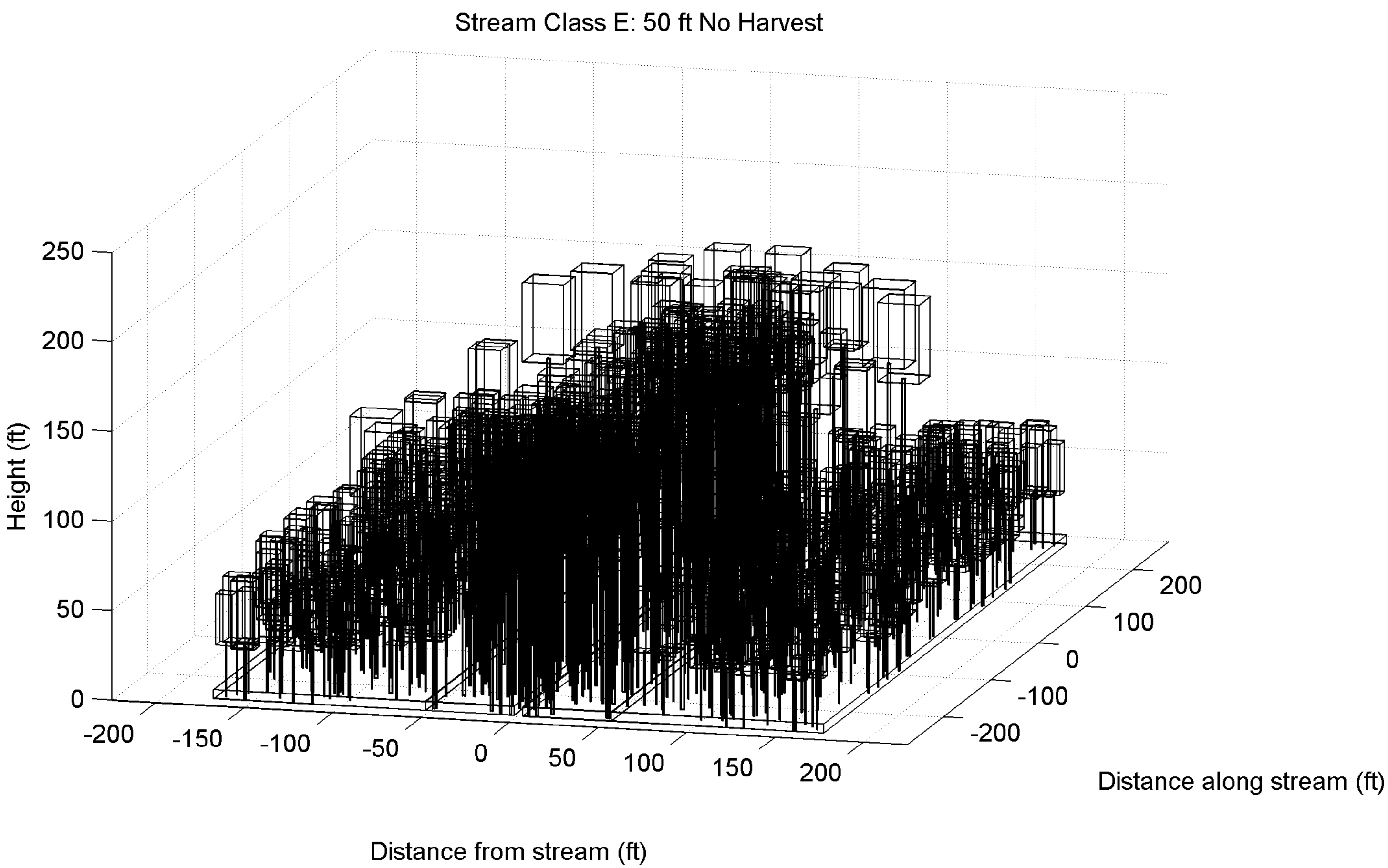


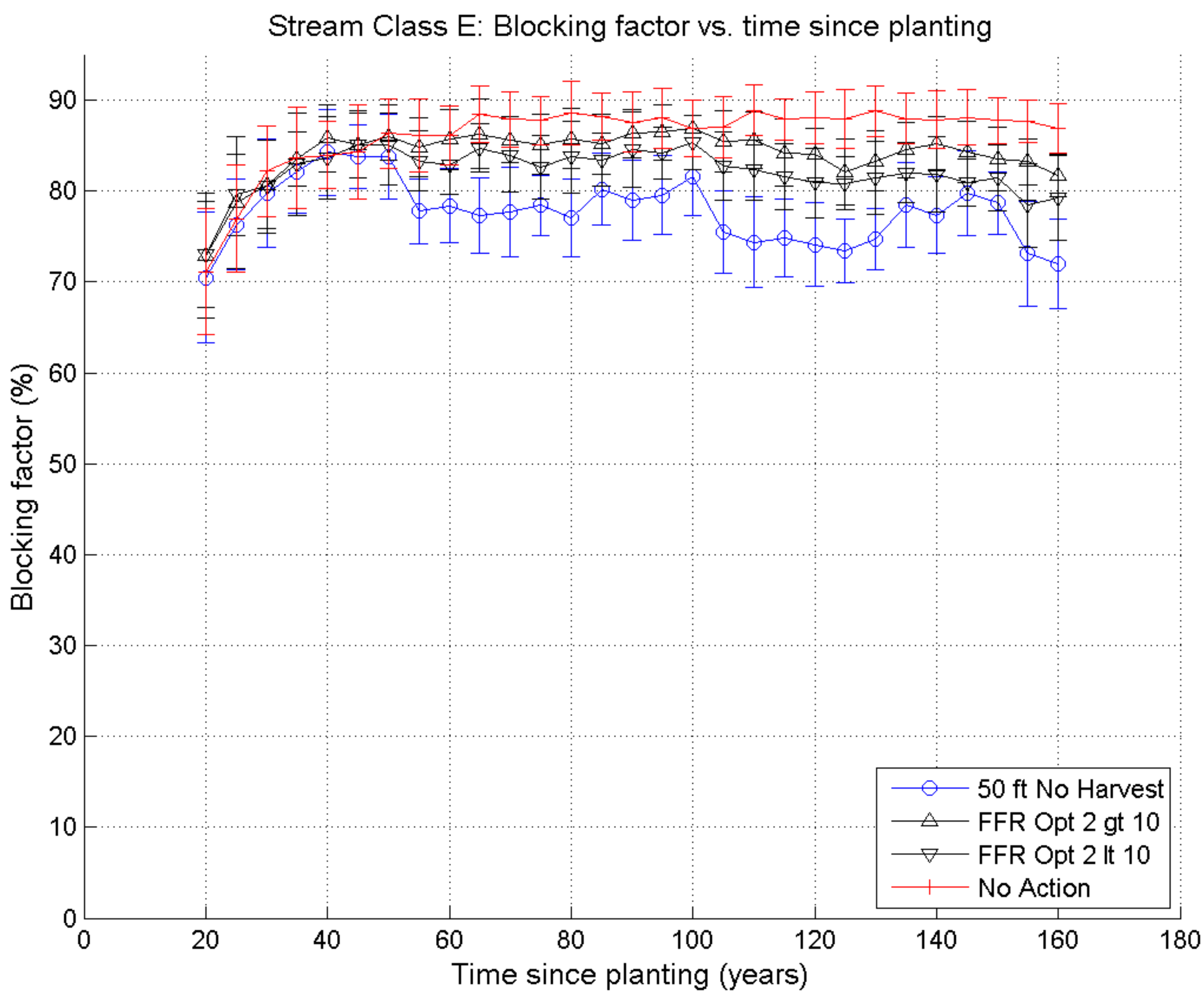
Stream Class A: Blocking factor vs. time since planting
Blocking factor (%)
Time since planting (years)
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
140
160
180
50 ft No Harvest
FFR Opt 2 gt 10
FFR Opt 2 lt 10
No Action


Stream Class E: No Action
Height (ft)
250
200
150
100
50
0
-200
-150
-100
-50
0
50
100
150
200
Distance from stream (ft)
200
100
0
-100
-200
Distance along stream (ft)



Stream Class E: FFR Opt 2 It 10
Height (ft)
250
200
150
100
50
0
-200
-150
-100
-50
0
50
100
150
200
Distance from stream (ft)
200
100
0
-100
-200
Distance along stream (ft)


Stream Class E: 50 ft No Harvest
Height (ft)
250
200
150
100
50
0
-200
-150
-100
-50
0
50
100
150
200
Distance from stream (ft)
200
100
0
-100
-200
Distance along stream (ft)


Stream Class E: Blocking factor vs. time since planting
Blocking factor (%)
Time since planting (years)
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
160
180
50 ft No Harvest
FFR Opt 2 gt 10
FFR Opt 2 lt 10
No Action