A Nonparametric Method for Defining and Using Biologically Based Targets in Forest Management

Kevin R. Gehringer
University of Washington
2003 SSAFR Conference
Stevenson, Washington, October 7-9, 2003

Overview

- Motivation
- Target definition issues
- Conceptual approach
- Example: Targets for riparian zone management

Motivation

- Washington State Forests and Fish Law
  - Passed in 1999
  - Final rules adopted in 2001
- Rules define quantitative management targets for potentially fish bearing streams in Western Washington (among other things)

Forests and Fish Rules

- Identifies unmanaged mature riparian forests, stands 80 to 200 years old, as a desired future condition (DFC) for managed stands
- Specifies minimum conifer basal area per acre targets by site class using mean conifer basal area per acre values
- 140 year reference age for mature stand
- The desired conditions represent moderate to lower density stands having diverse structures and moderate to large trees

Target Definition Issues

- The inherent or natural variability of forest ecosystems
  - Forest ecosystems are highly variable
  - This variability must be taken into account when defining targets for management

Target Definition Issues (cont.)

- Forest ecosystems are multidimensional
  - No single attribute or value for an attribute can adequately represent the structure, composition, or function of a forest
  - For any attribute value a range of possible values exists for other attributes
  - Attribute values are typically coupled, e.g., size-density relationships

Target Definition Issues (cont.)

- If a target is defined, a compatible assessment procedure is necessary
  - We need to be able to tell when the target conditions have been achieved
  - Target definition and assessment procedures are linked

Target Definition Issues (cont.)

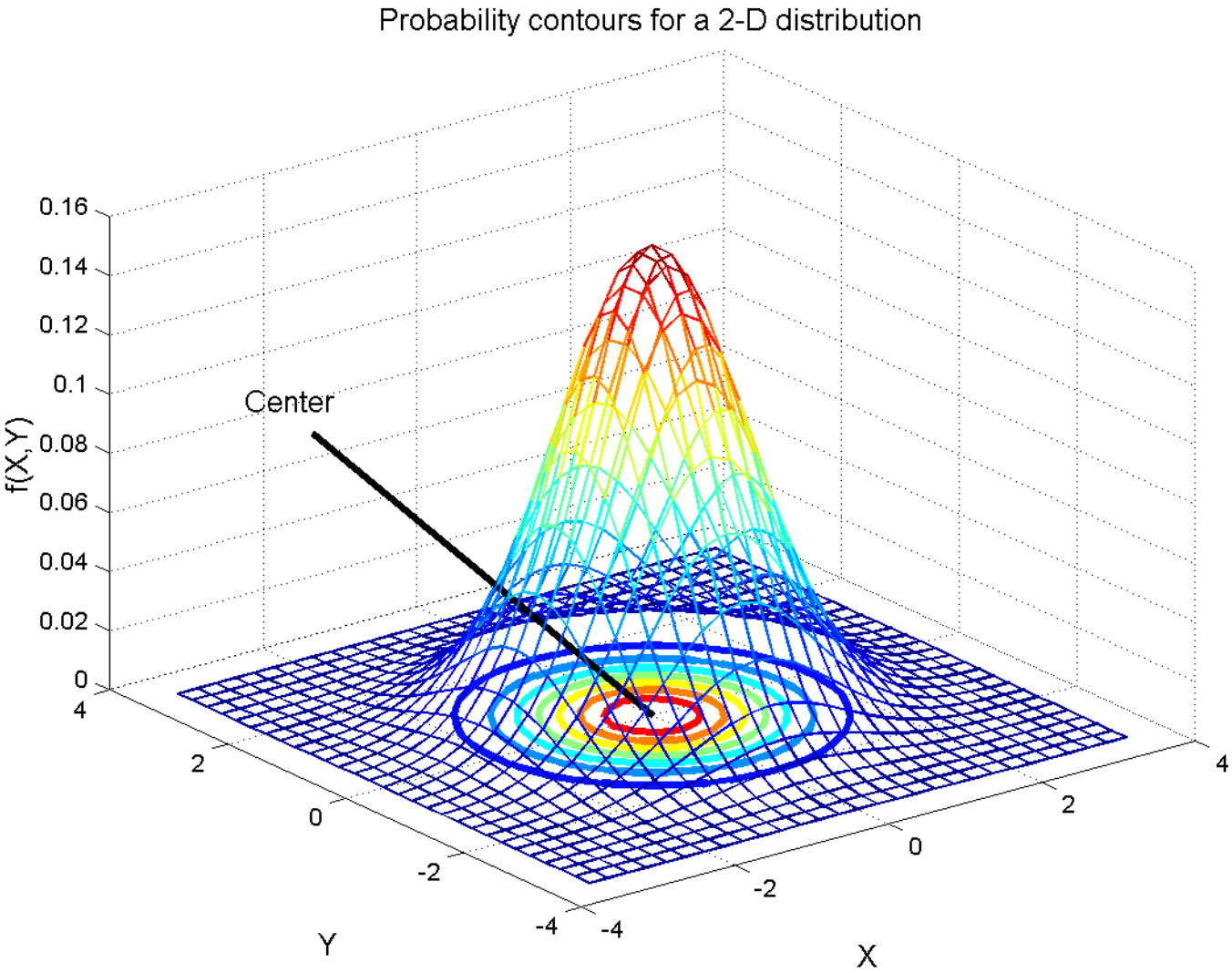
- Target definition and assessment procedures must be objective and biologically and statistically consistent
  - Independent assessments of a particular situation should give the same results
  - The target and assessment procedures must be compatible with each other and with the biology through available data

Conceptual Approach

- A forested area may be described using coupled values for a set of attributes:
  - TPA, QMD, average tree height, species composition, etc.
- For some collection of forest stands a distribution of the attribute values exists
- The distribution can be used to define a neighborhood of acceptable values

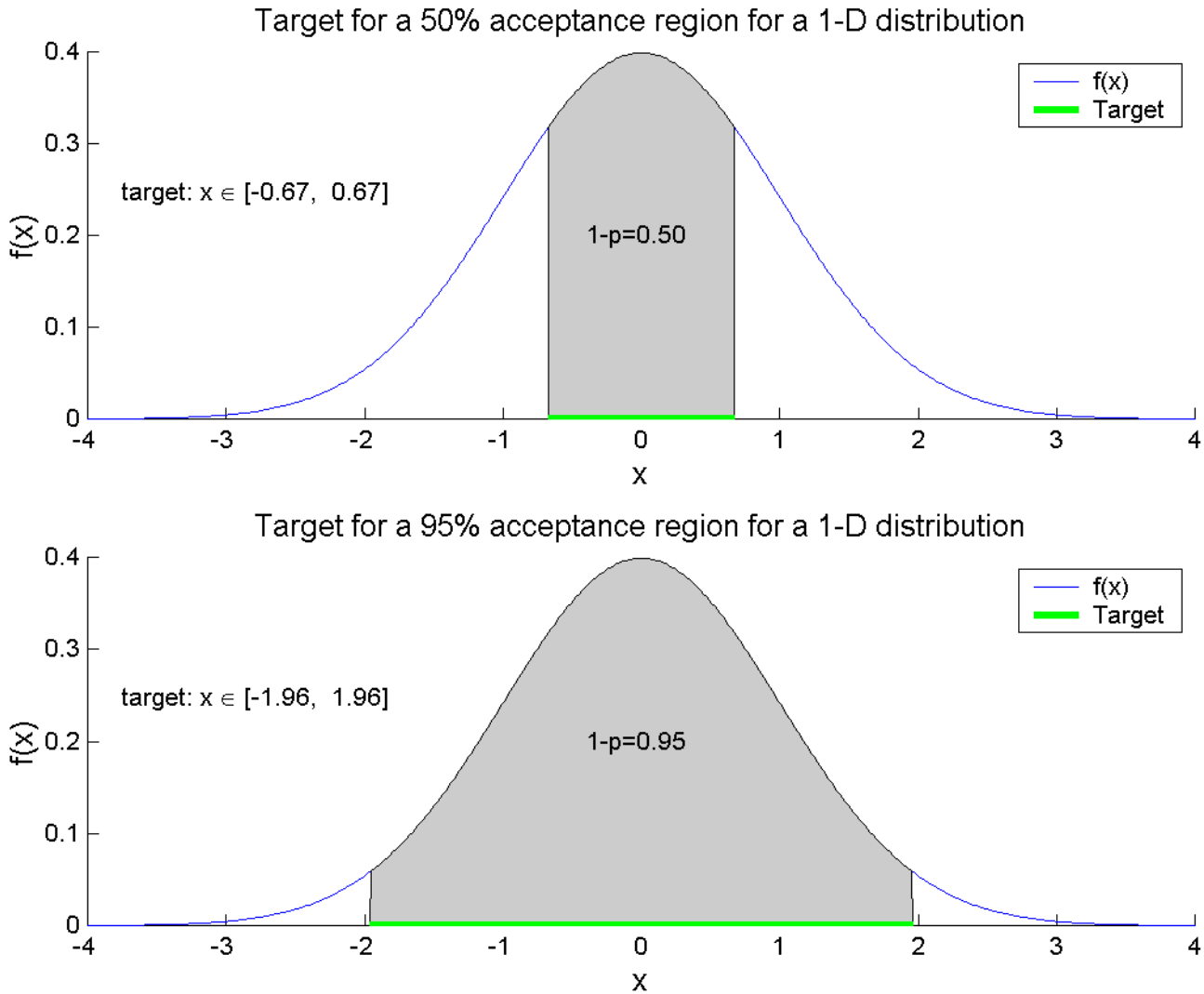
Target Definition

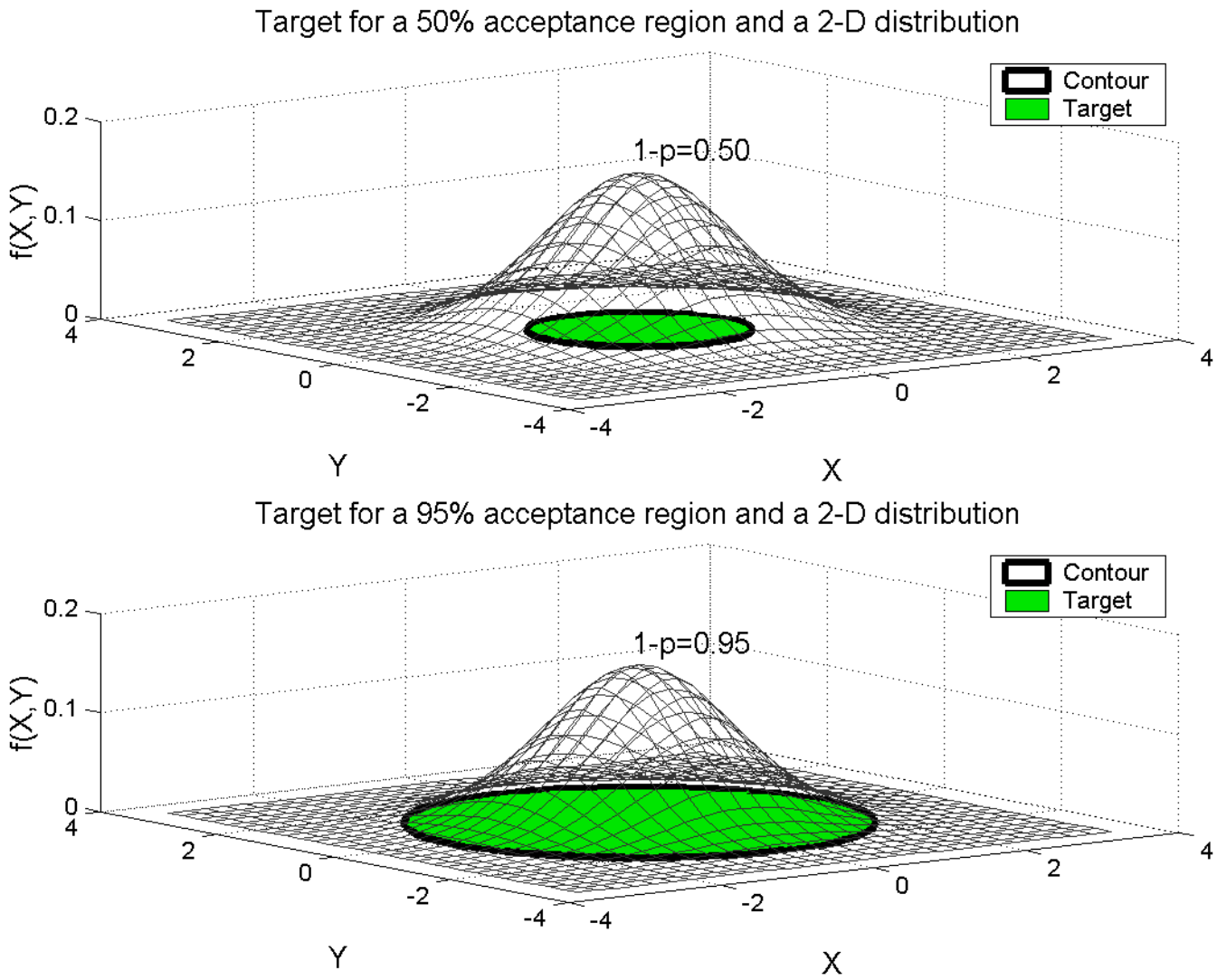
- Probability contours are used to define a target using the distribution for some set of attribute values
- The highest probability or most likely attribute values are selected (targeted) first and form the *center* of a target


Probability contours for a 2-D distribution
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
f(X,Y)
Center
4
2
0
-2
-4
Y
-4
-2
0
2
4
X

Target Definition (cont.)

- The target extent is controlled by specifying a rejection level *p*
  - *p* is similar to the *α*-level in hypothesis testing
  - 1-*p* is then an acceptance probability defining a (1-*p*)100% acceptance level
  - The contour for an acceptance level then identifies an acceptance region or *target*


Target for a 50% acceptance region for a 1-D distribution
f(x)
Target
target: x ∈ [-0.67, 0.67]
1-p=0.50
f(x)
X
Target for a 95% acceptance region for a 1-D distribution
f(x)
Target
target: x ∈ [-1.96, 1.96]
1-p=0.95
f(x)
X


Target for a 50% acceptance region and a 2-D distribution
Contour
Target
1-p=0.50
f(X,Y)
0.2
0.1
0
4
2
0
-2
-4
-4
-2
0
2
4
Y
X
Target for a 95% acceptance region and a 2-D distribution
Contour
Target
1-p=0.95
f(X,Y)
0.2
0.1
0
4
2
0
-2
-4
-4
-2
0
2
4
Y
X

Assessment Procedure

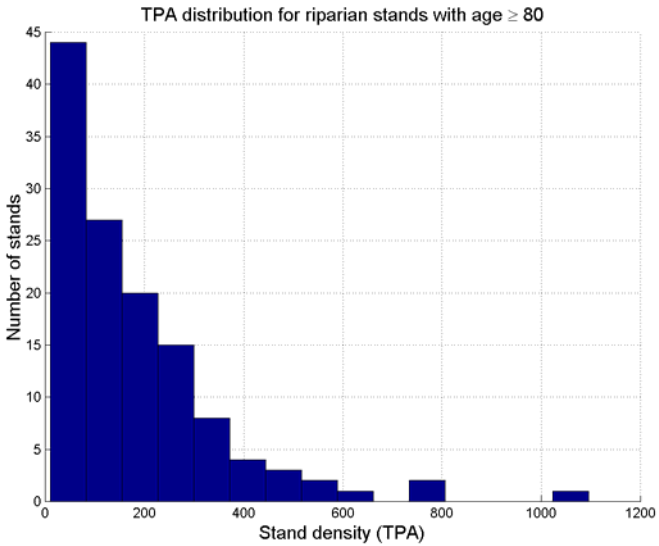
- Given a target data set, an observation, and a (1-*p)100%* acceptance level we want to answer the question:
  - Is the observation indistinguishable from the target?
- This is done in two steps
  1. Find the contour for the acceptance level
  2. Test whether the observation is inside the contour (acceptable) or not (unacceptable)

Distribution

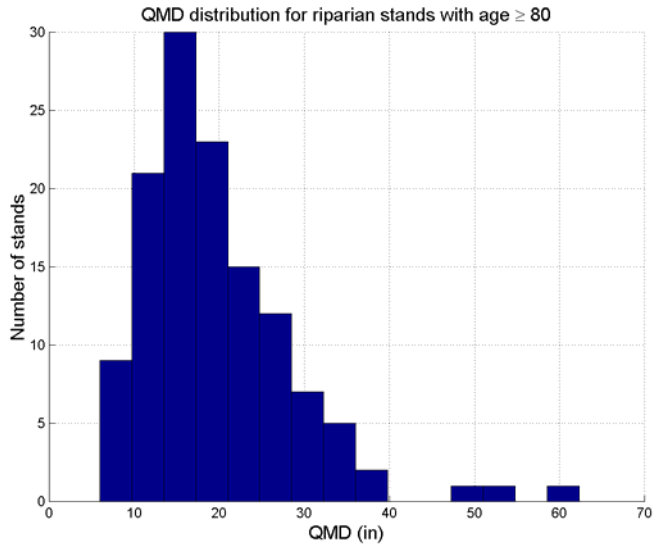
- To specify a target we need a distribution
- The form or shape of the distribution is generally unknown
- We, therefore, need
  - A sample that is representative of the distribution of desired conditions to define the target
  - A procedure for obtaining probability contours from the sample

Distribution (cont.)

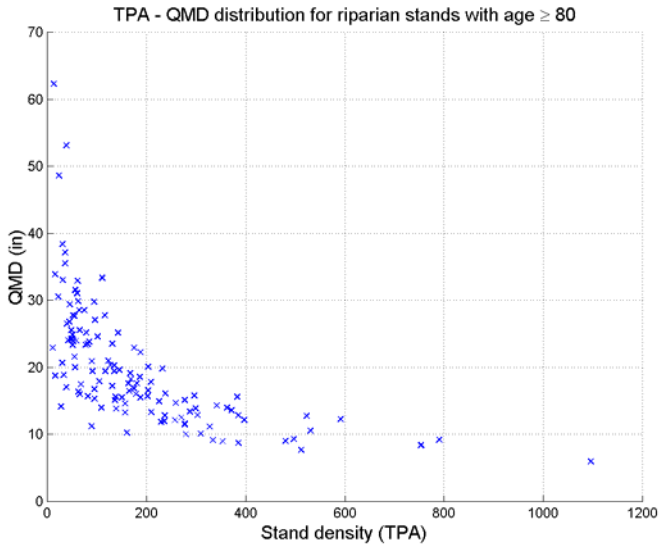
- A joint distribution is required if using multiple variables: all variables must be considered simultaneously
  - Cannot be done by using distributions for each attribute separately
- Example
  - Stand density – quadratic mean diameter distribution


TPA distribution for riparian stands with age ≥ 80
Number of stands
Stand density (TPA)
0
5
10
15
20
25
30
35
40
45
0
200
400
600
800
1000
1200

+


QMD distribution for riparian stands with age ≥ 80
Number of stands
QMD (in)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70

≠


TPA - QMD distribution for riparian stands with age ≥ 80
QMD (in)
Stand density (TPA)
0
10
20
30
40
50
60
70
0
200
400
600
800
1000
1200

Distribution (cont.)

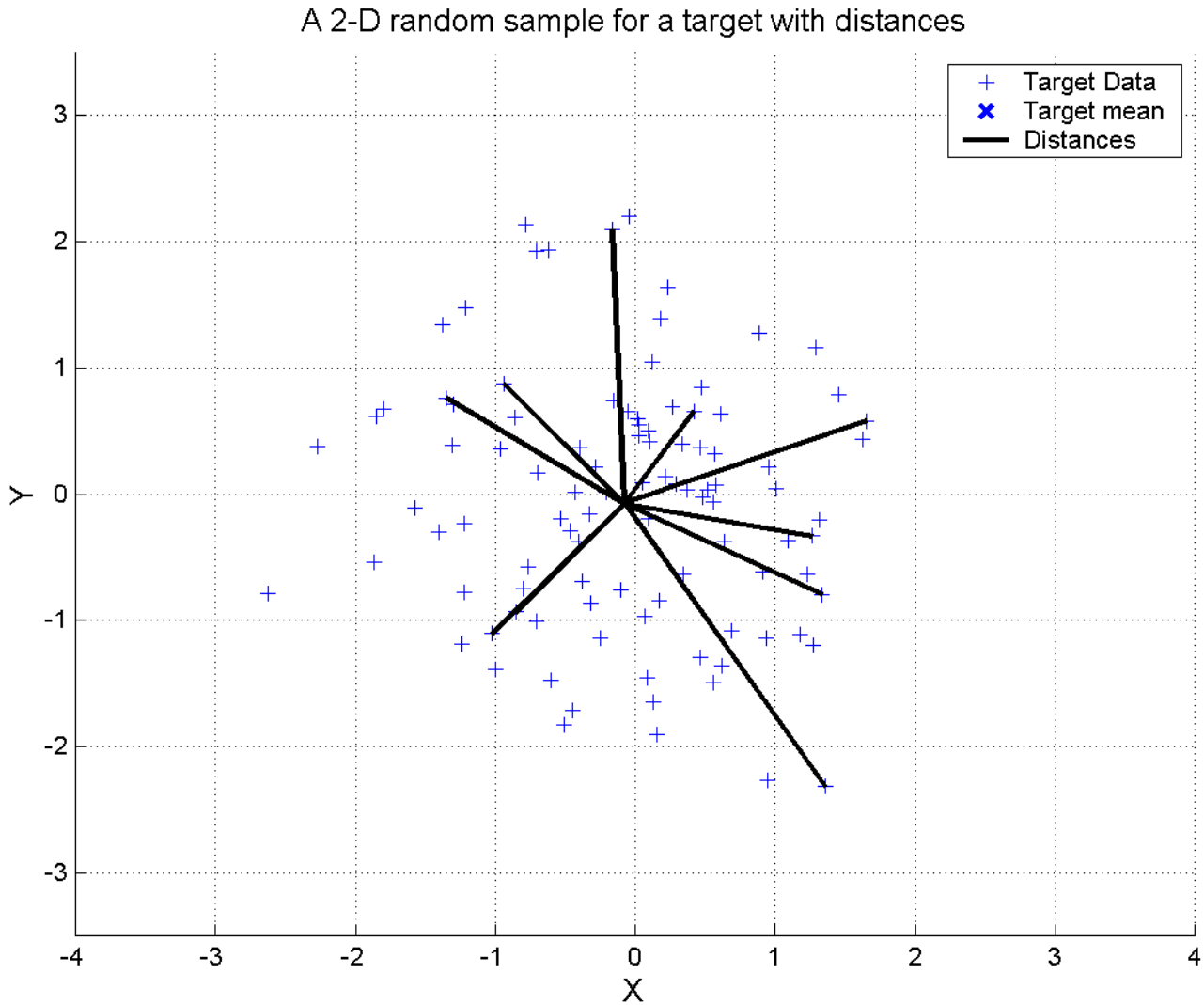
- A nonparametric representation was used for the unknown attribute value distribution
  - Compatible with the distribution of the data
  - Considers all attributes simultaneously, so the joint distribution is automatically used
  - Can be used with any distribution shape

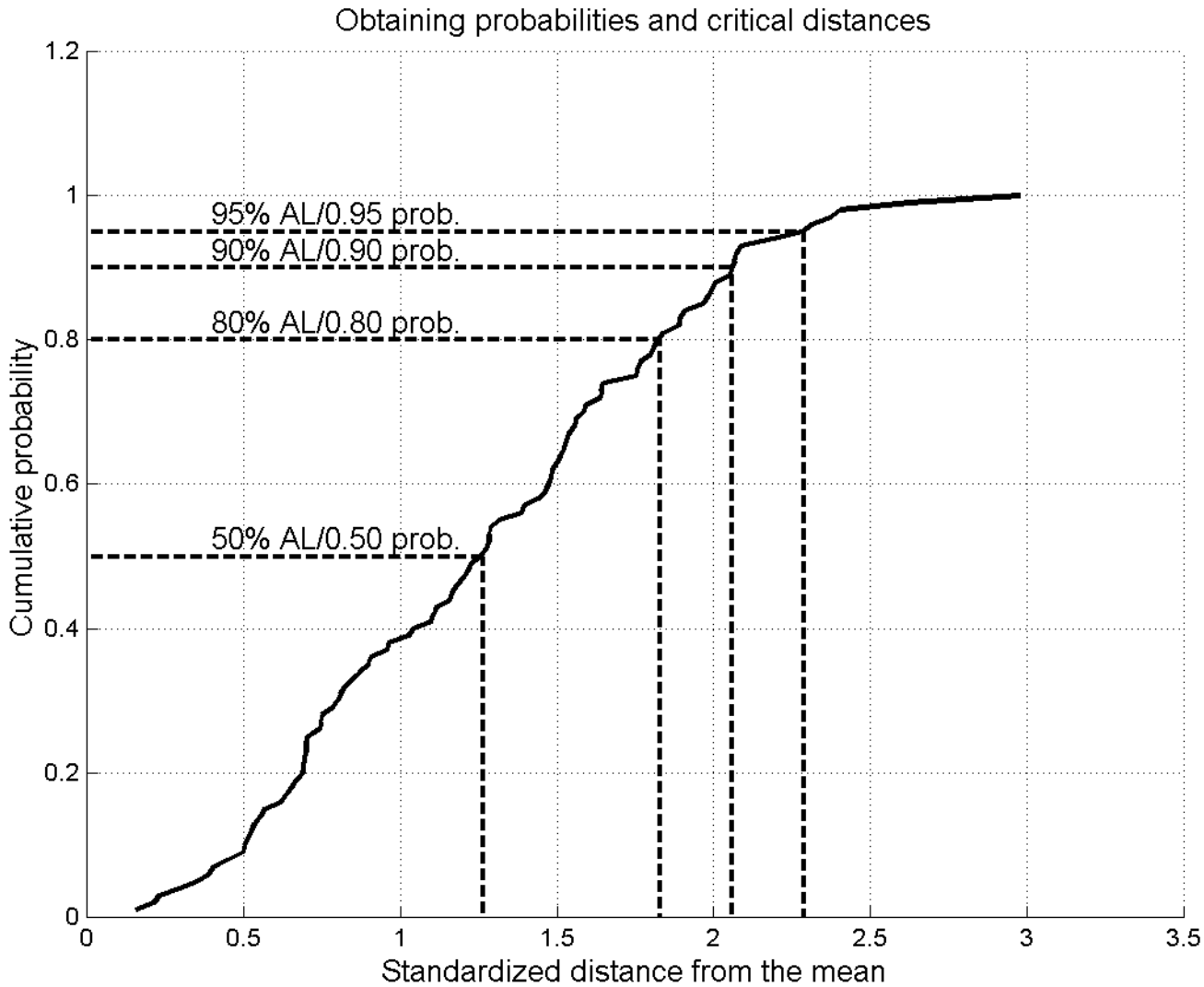
Distribution (cont.)

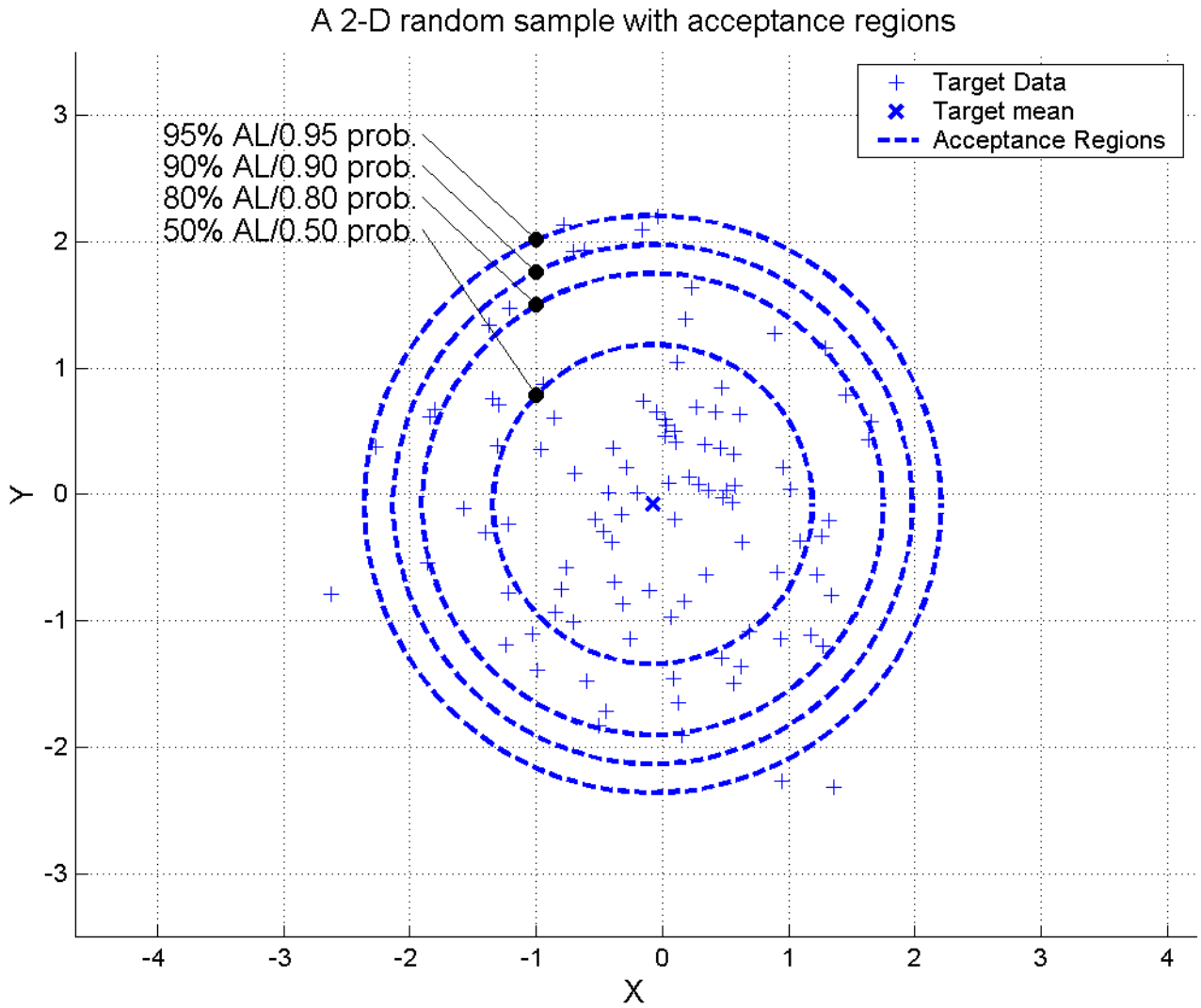
- To simplify the probability and critical contour calculations, we require the attribute value distribution to be
  - Unimodal (has one peak)
  - Reasonably symmetric
  - Continuous
- Critical contours and probabilities are then defined by distances from a central value

Critical Distance and Probability

- Critical contours and probabilities were determined using the empirical cumulative distribution function for standardized distances from a central value


A 2-D random sample for a target with distances
Target Data
Target mean
Distances
Y
X
3
2
1
0
-1
-2
-3
-4
-3
-2
-1
0
1
2
3
4


Obtaining probabilities and critical distances
95% AL/0.95 prob.
90% AL/0.90 prob.
80% AL/0.80 prob.
50% AL/0.50 prob.
Cumulative probability
Standardized distance from the mean
0
0.2
0.4
0.6
0.8
1
1.2
0
0.5
1
1.5
2
2.5
3
3.5


A 2-D random sample with acceptance regions
Target Data
Target mean
Acceptance Regions
95% AL/0.95 prob.
90% AL/0.90 prob.
80% AL/0.80 prob.
50% AL/0.50 prob.
X
Y
3
2
1
0
-1
-2
-3
-4
-3
-2
-1
0
1
2
3
4

Riparian Target Example

- Targets were defined within the context of the Forests and Fish Rules
- Emphasize mature forest structure
  - Structural characteristics of forest stands within a riparian zone are used to define desired riparian forest conditions
  - Consider targets using from one to three stand attributes

Data Source and Selection Criteria

- Data Source
  - FIA PRIME database
- Data selection Criteria
  - Western Washington riparian forests
  - Trees greater than 4 inch DBH included
  - Plots within 215 feet of a stream
  - Mature stands: stand age at least 80 years by FIA age class

Data Summary

- 127 riparian plots
- Stand ages from 80 to over 300 years
- Stand attributes used to define targets
  - BA Basal area per acre
  - CBA Conifer only basal area per acre
  - TPA Trees per acre
  - QMD Quadratic mean diameter
  - H Average tree height

Target and Observations

- The target data set contains mature stands with ages from 100 to 180 years
  - 42 of the 127 plots or 33% or the plots
  - The mode of the target data was used as the central value
- The observation data set contains the entire set of riparian plots
  - 127 plots

Assessment Scenarios

1. BA, CBA
   - Frequently used as structural variables
2. TPA and QMD
   - Distinguishes between dense stands and sparse stands having the same BA of CBA values
3. TPA, QMD, and average height (H)
   - Tree height is important for shade and woody debris recruitment

Assessments

- Assessments were performed using four acceptance levels
  - 95%, 90%, 80%, 50%
- Acceptance percentages and relative acceptance percentages were computed for each acceptance level
  - A relative acceptance percentage is the ratio of the acceptance percentage to the acceptance level

Results

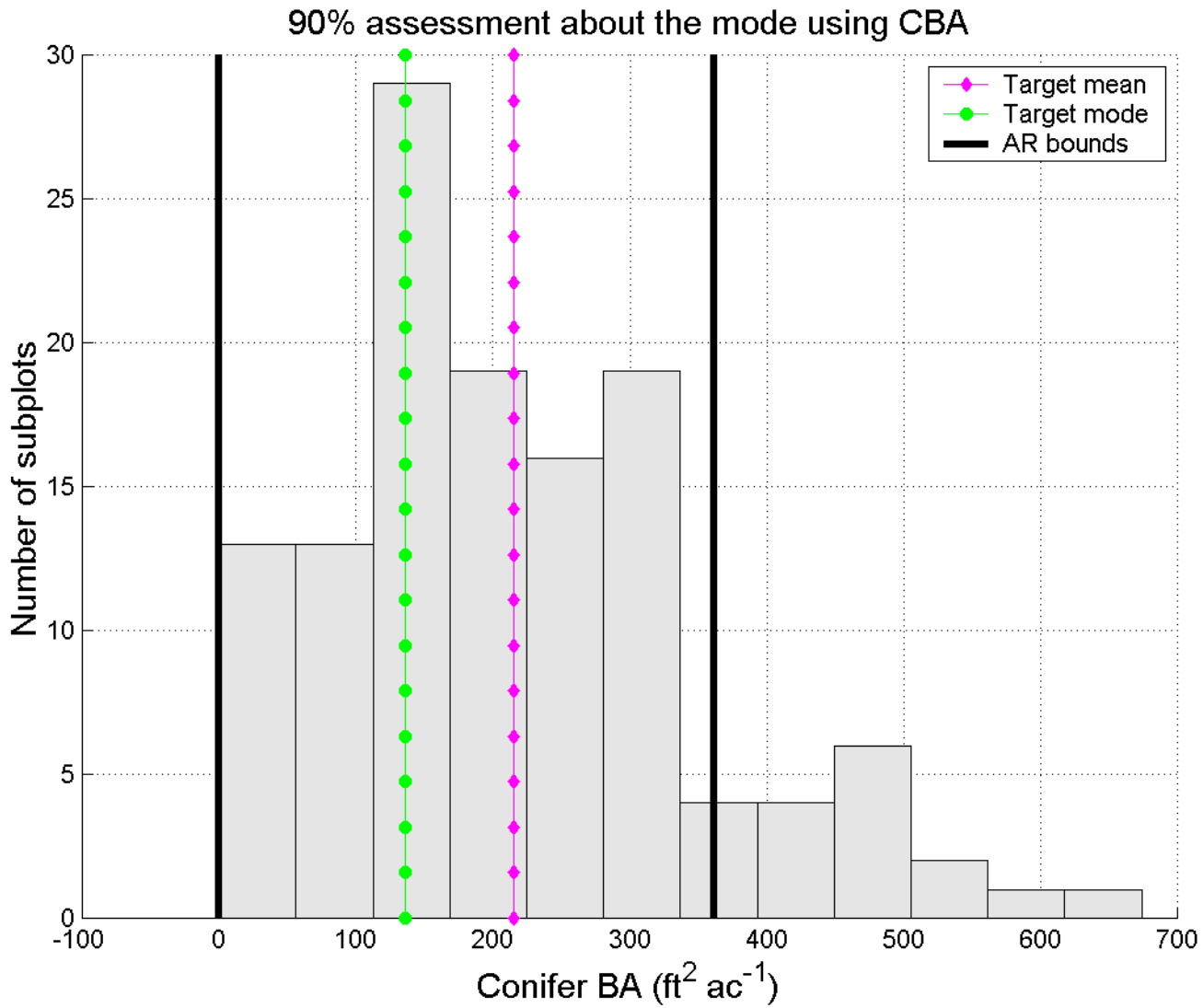
Acceptance Percentages (Relative Acceptance Percentages)				
Scenario	Acceptance Level			
	95%	90%	80%	50%
BA	94 (99)	87 (98)	74 (93)	42 (74)
CBA	95 (100)	88 (98)	75 (92)	44 (91)
TPA, QMD	89 (94)	84 (82)	76 (75)	57 (59)
TPA, QMD, H	89 (94)	80 (88)	72 (90)	45 (90)

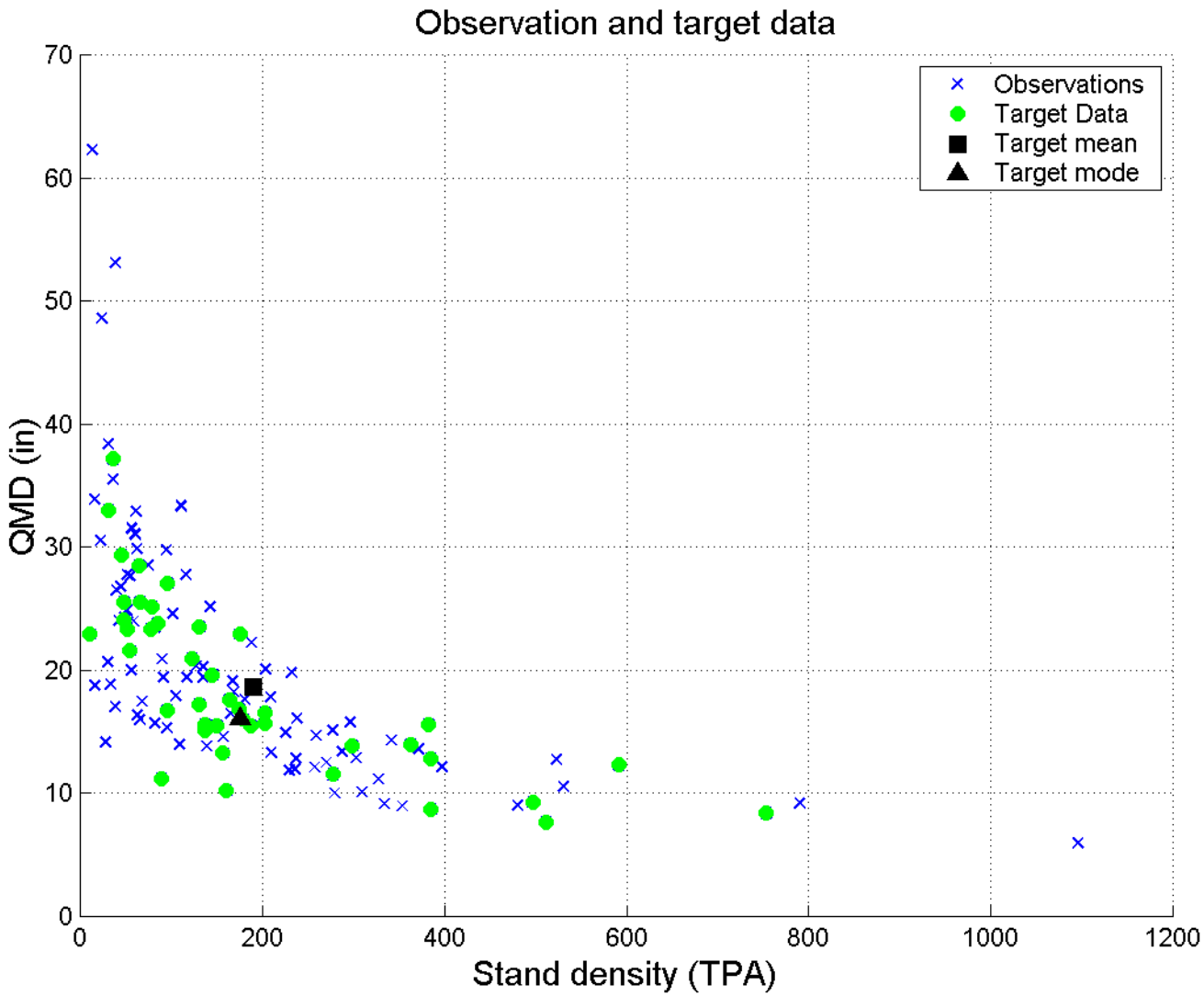
Results (cont.)

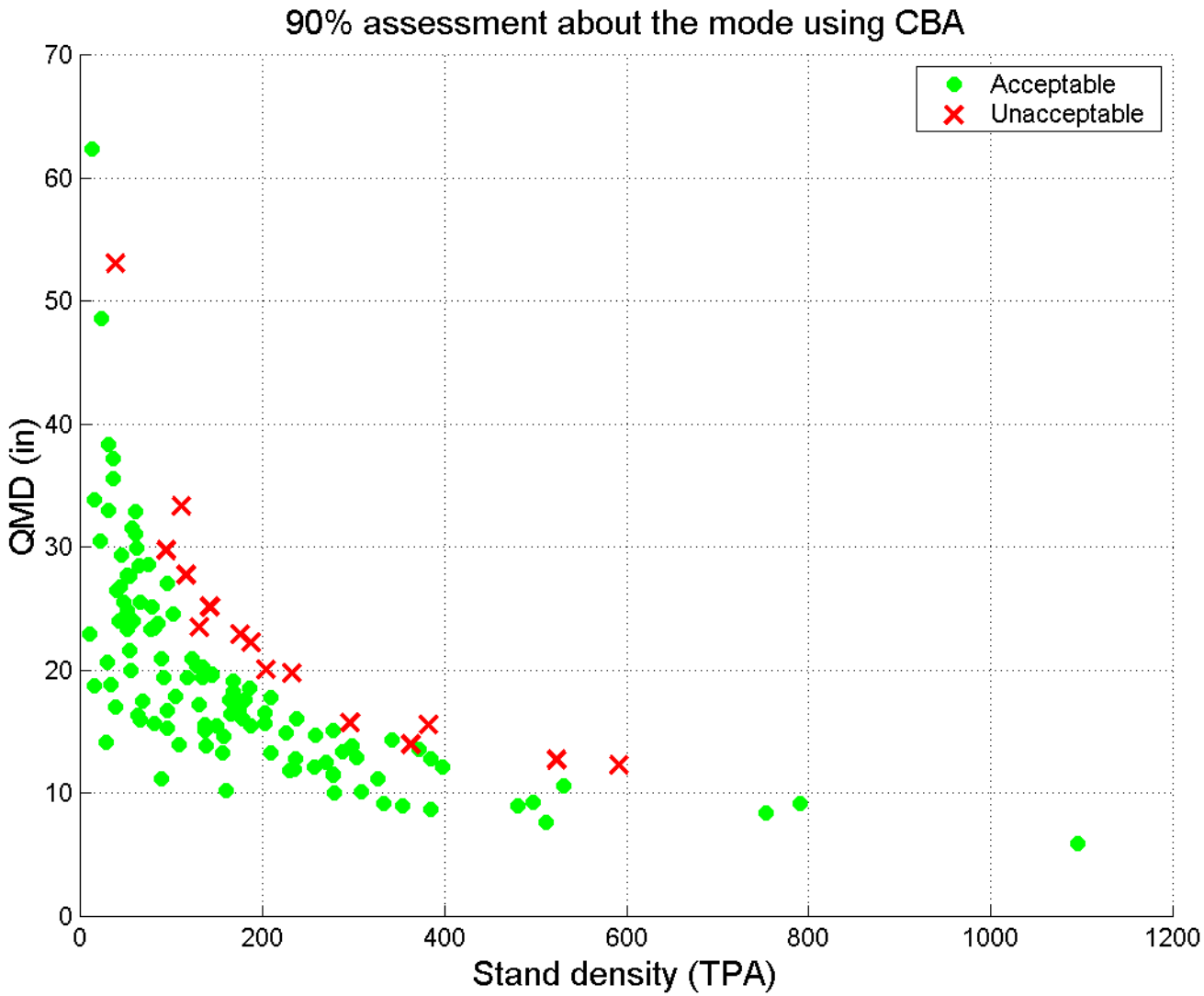
- All scenarios appeared to work well
  - Acceptance percentages agree with acceptance levels
- Did all scenarios identify stands that were similar to the desired conditions?
  - Moderate to low density
  - Larger average tree sizes
- Consider the 90% acceptance level

CBA Results

- 88% acceptance percent, 98% of acceptance level
- Results for BA are similar
  - 87% acceptance percent, 98% of acceptance level

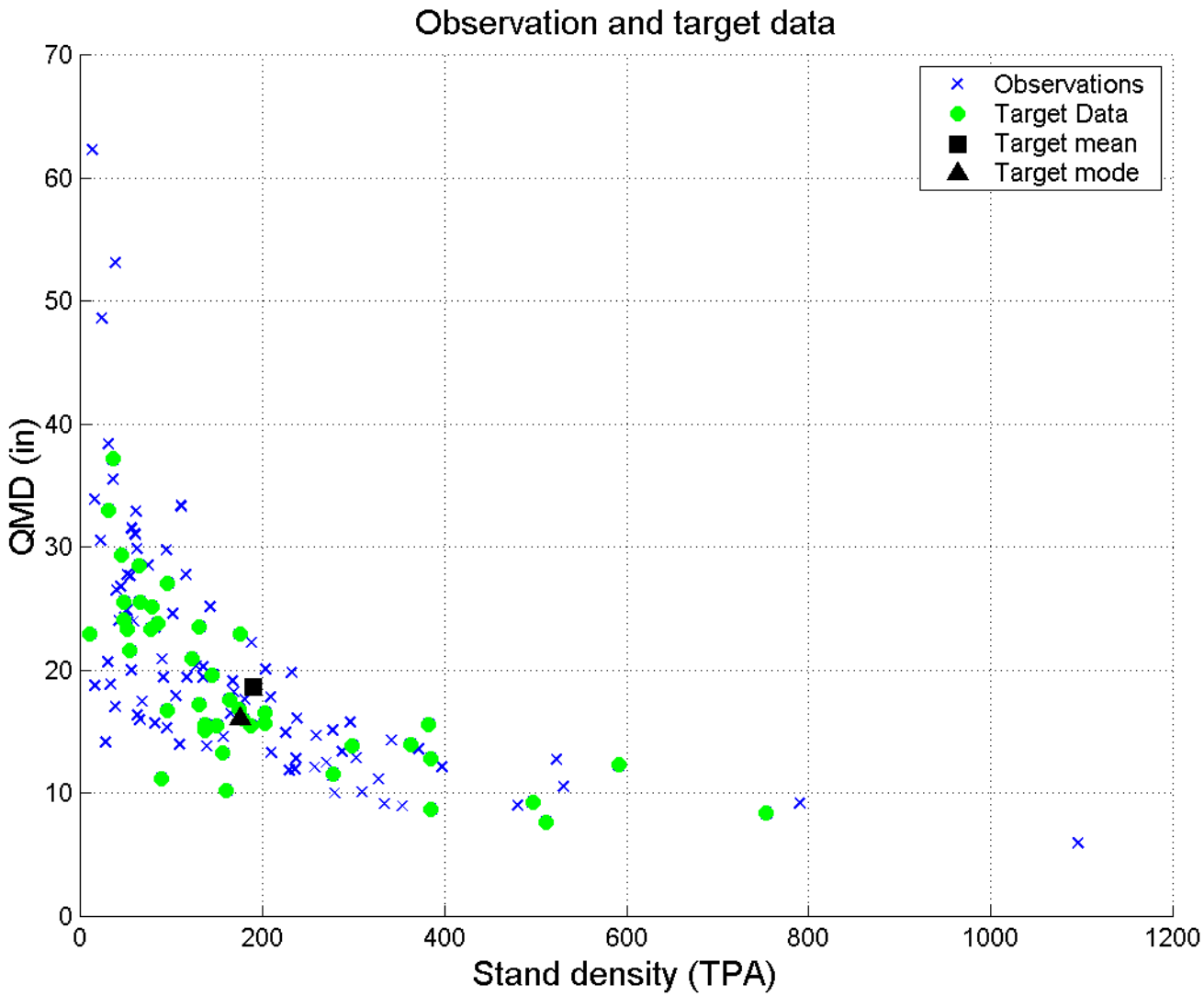

90% assessment about the mode using CBA
Target mean
Target mode
AR bounds
Number of subplots
Conifer BA (ft2 ac-1)
0
5
10
15
20
25
30
-100
0
100
200
300
400
500
600
700

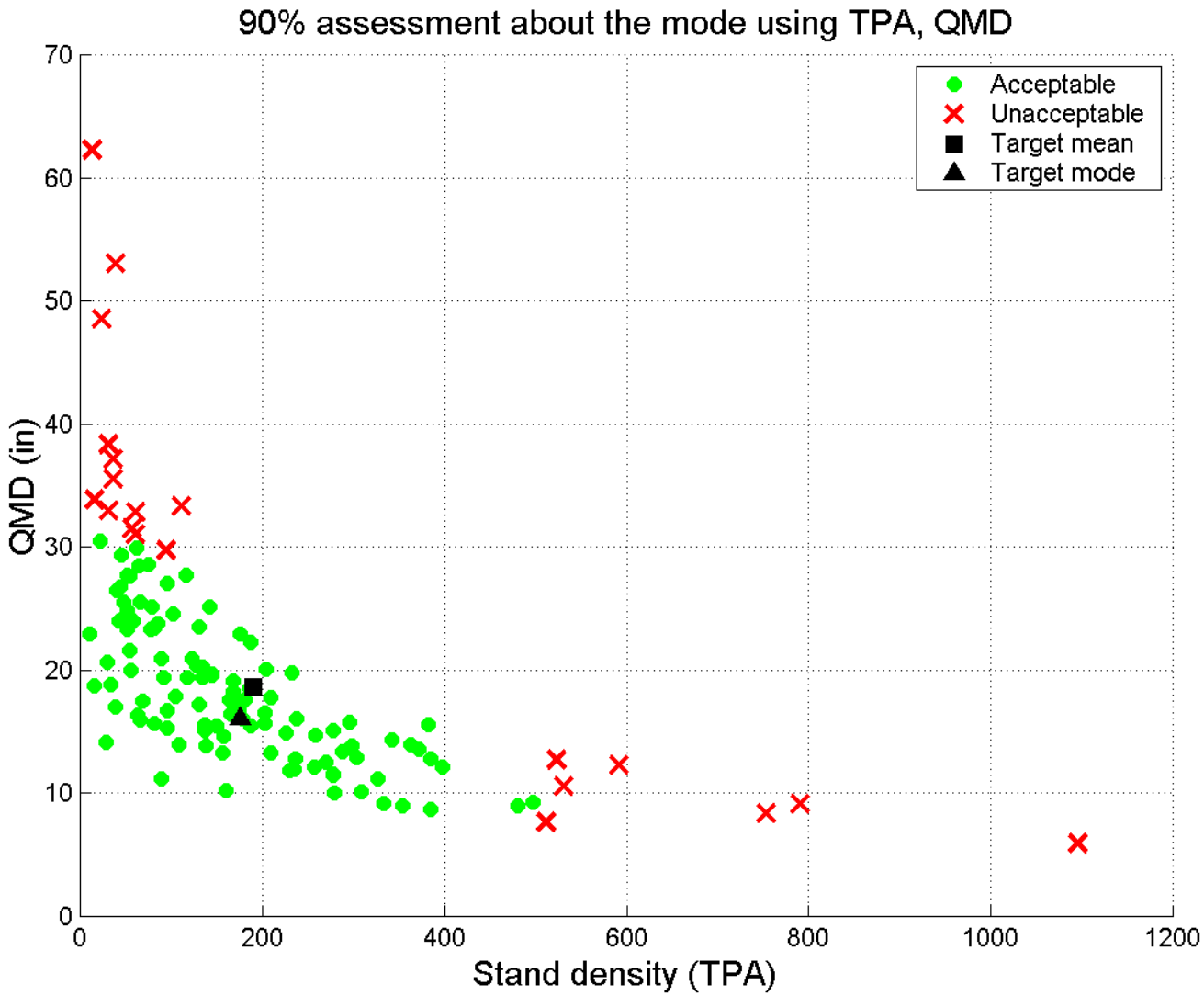

Observation and target data
Observations
Target Data
Target mean
Target mode
QMD (in)
Stand density (TPA)
0
10
20
30
40
50
60
70
0
200
400
600
800
1000
1200


90% assessment about the mode using CBA
Acceptable
Unacceptable
QMD (in)
Stand density (TPA)
0
10
20
30
40
50
60
70
0
200
400
600
800
1000
1200

TPA and QMD Results

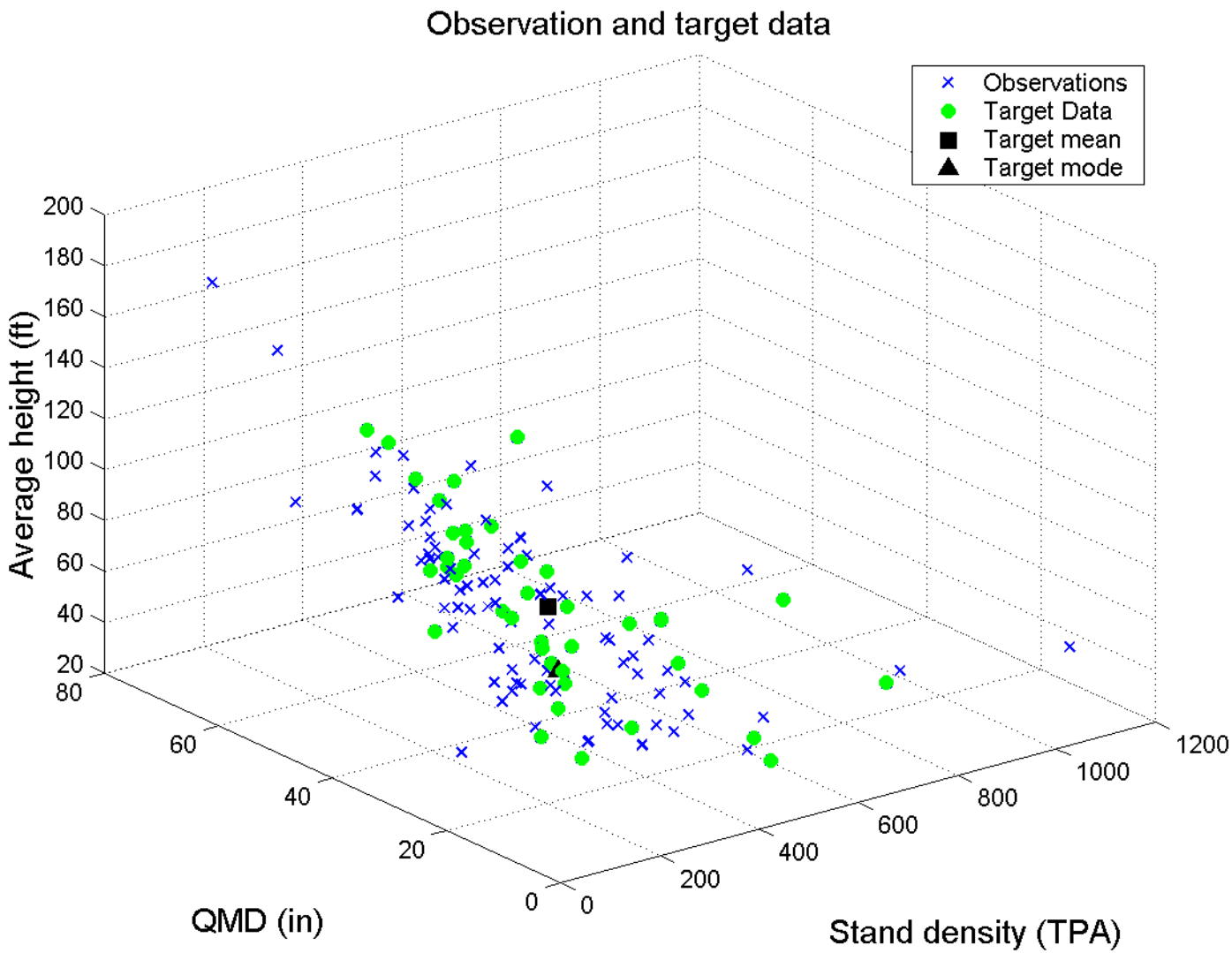
- 82% acceptance percent, 93% of acceptance level

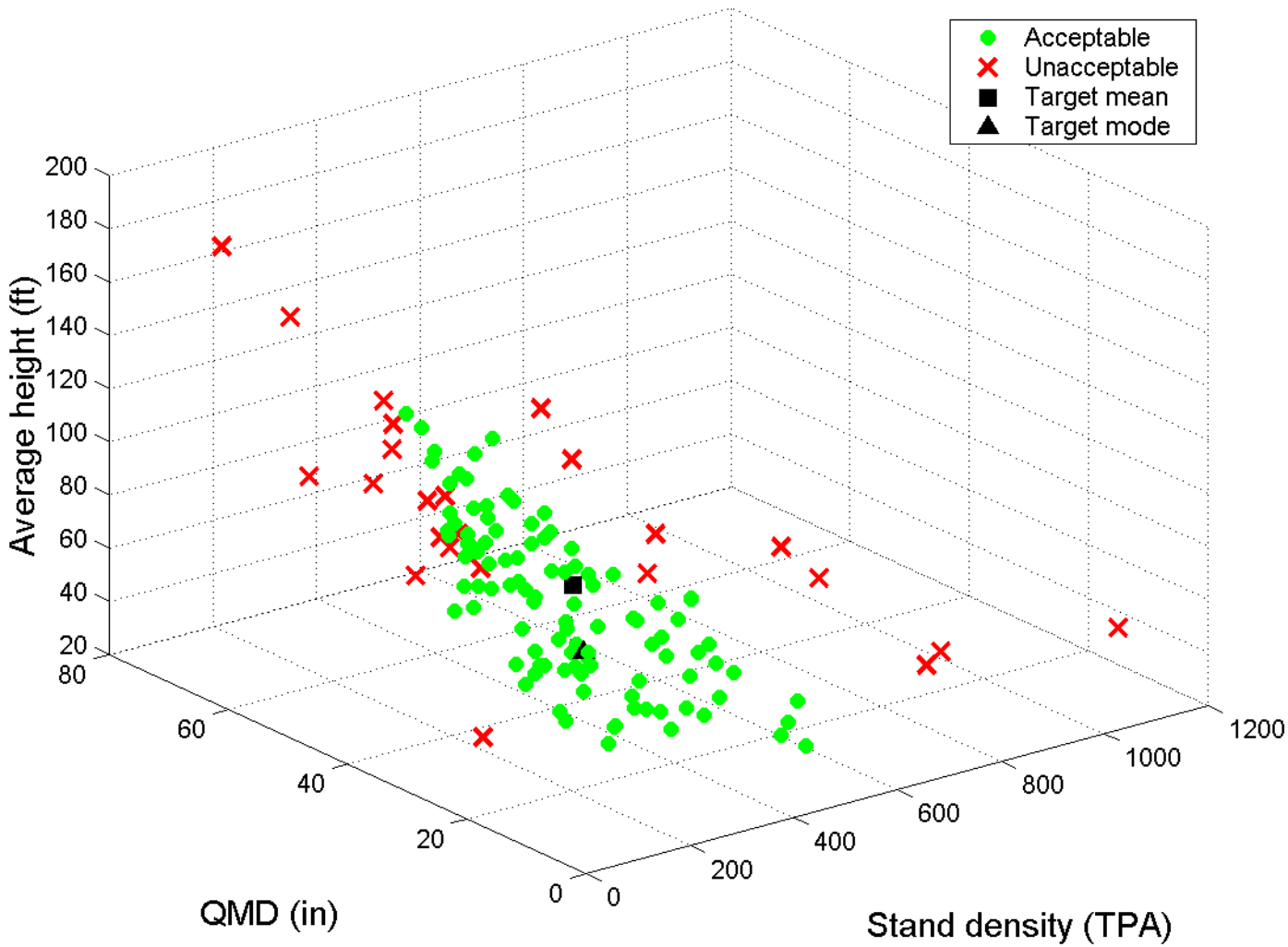

Observation and target data
Observations
Target Data
Target mean
Target mode
QMD (in)
Stand density (TPA)
0
10
20
30
40
50
60
70
0
200
400
600
800
1000
1200


90% assessment about the mode using TPA, QMD
Acceptable
Unacceptable
Target mean
Target mode
QMD (in)
Stand density (TPA)
0
10
20
30
40
50
60
70
0
200
400
600
800
1000
1200

TPA, QMD, H Results

- 80% acceptance percent, 88% of acceptance level


Observation and target data
Observations
Target Data
Target mean
Target mode
Average height (ft)
200
180
160
140
120
100
80
60
40
20
80
60
40
20
0
QMD (in)
0
200
400
600
800
1000
1200
Stand density (TPA)


90% assessment about the mode using TPA, QMD, H
Acceptable
Unacceptable
Target mean
Target mode
Average height (ft)
200
180
160
140
120
100
80
60
40
20
QMD (in)
80
60
40
20
0
Stand density (TPA)
0
200
400
600
800
1000
1200

Conclusions

- The target definition and assessment procedures performed well
- Using multidimensional targets better identified a set of desired conditions
- Target definition and assessment procedures were statistically consistent
- Biological constraints were enforced via the attributes used to define a target

Conclusions (cont.)

- Key points
  - Hard limits for each attribute were not necessary
    - Instead probability contours were used
    - Based on the distribution of the attributes
    - Attributes were considered simultaneously
  - Hard boundaries were however defined by the acceptance level

The End