Quantitative Management of Plantation in China

Dr. Jinghui Meng

Beijing Forestry University

北京林业大学
Beijing Forestry University

Plantations in China

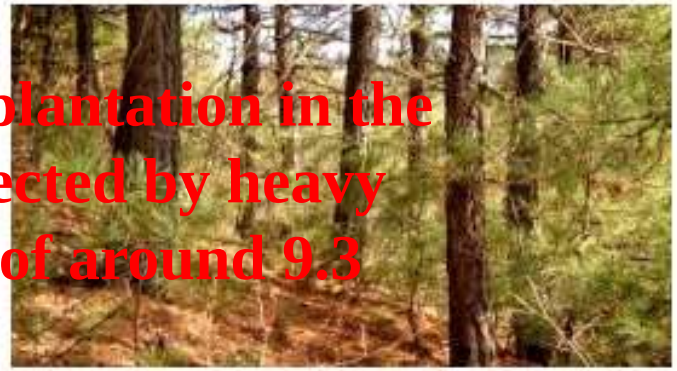
- China has the largest areas of planation in the world
  - 69.0 million hectares and 2.5 billion cubic meters
- Plantation is still increasing
  - In the past 60 years, 241 million hectares was established
  - From 2009 to 2013, the plantation has been increased by 7.7 million hectares

Plantations and their problems in China

- The role of planation in China
  - Timber production
    - China is the second largest timber consumer in the world
  - Ecological protection
    - The Tree-North Shelterbelt Project
    - Coastal windbreaks

The problem of plantation in China

- Low productivity and quality
  - The total stand volume is only 53.8 m^3 per hectare
  - Annual volume growth is 4.2 m^3 per hectare
- Highly susceptible to disturbance
  - Windthrow
  - Snow breakage
  - Fire



In 2008, about 18 million hectares of plantation in the subtropical regions of China were affected by heavy sleet and ice, causing economic losses of around 9.3 billion US Dollar

Current management systems

- A system of successive cropping is the current management regime for plantations
  - Plantation establishment
  - Intermediate thinning after canopy closure
  - Final clear cutting

Plantation establishment

Intermediate thinning

Final clearcutting

Current management systems

- The shortcomings of the current system
  - Mainly developed for timber production
  - Fixed rotation lengths and rigid thinning schedules

- Furthermore, it is extremely difficult to determine the rotation length and thinning schedules for various management objectives (timber production)!!!

- Field trials
  - Long-term observation period
  - Limited popularization of the trial results/less transferable

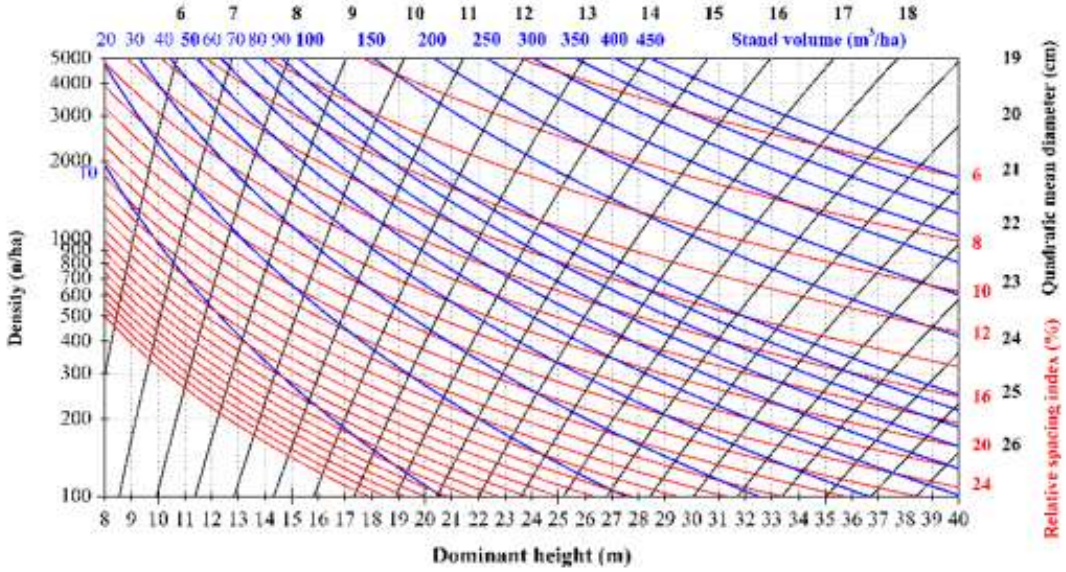
Solutions? **Stand density management diagram**

Stand density management

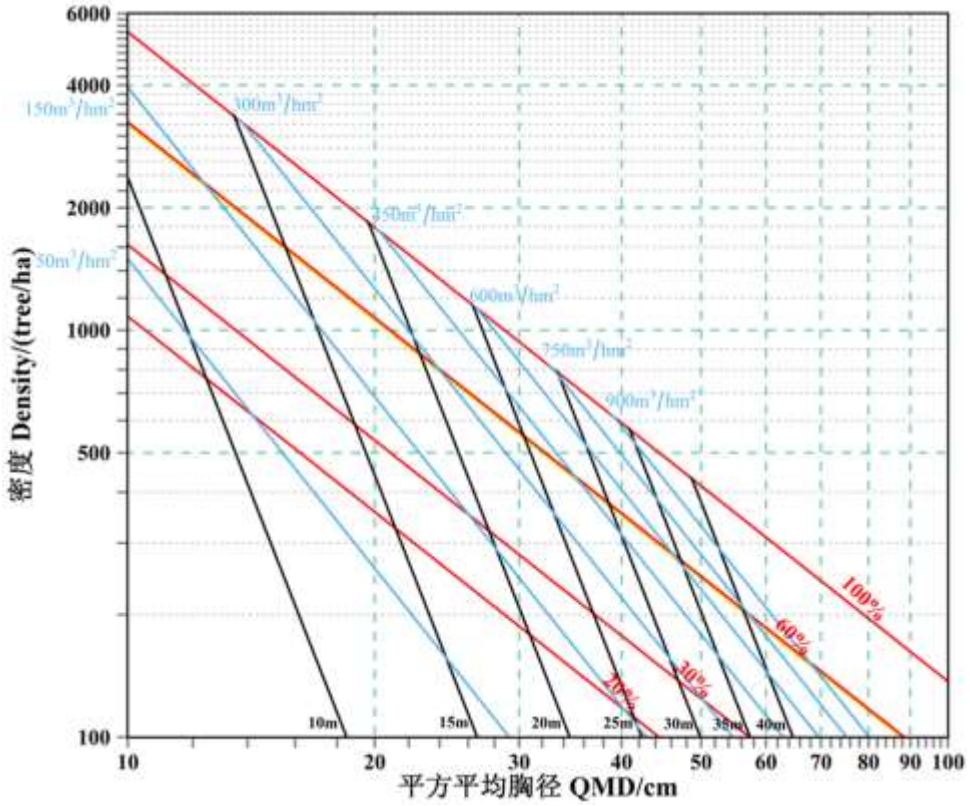
- Stand density management diagrams (SDMDs) are average stand-level models and can graphically reflect the relationships amongst yield, density and mortality throughout all stages of stand development
- SDMDs can provide the possibility of simulation of different management regimes and the development of thinning schedules for **a wide range of changing site qualities and management objectives**

Fundamental basis for SDMD

- The fundamental basis for SDMD is the **self-thinning rule**.
- There are two commonly indices for characterizing the self-thinning rule
  - The Reineke's stand density equation
  - The relative spacing index



Relative Spacing Index



Reineke Equation

We developed SDMDs for the following tree species with different objectives

- Masson pine (*Pinus massoniana*)
  - Timber production
  - Reineke equation
- Beach sheoak (*Casuarina equisetifolia*)
  - Windthrow risk reduction
  - Relative spacing index

Part I

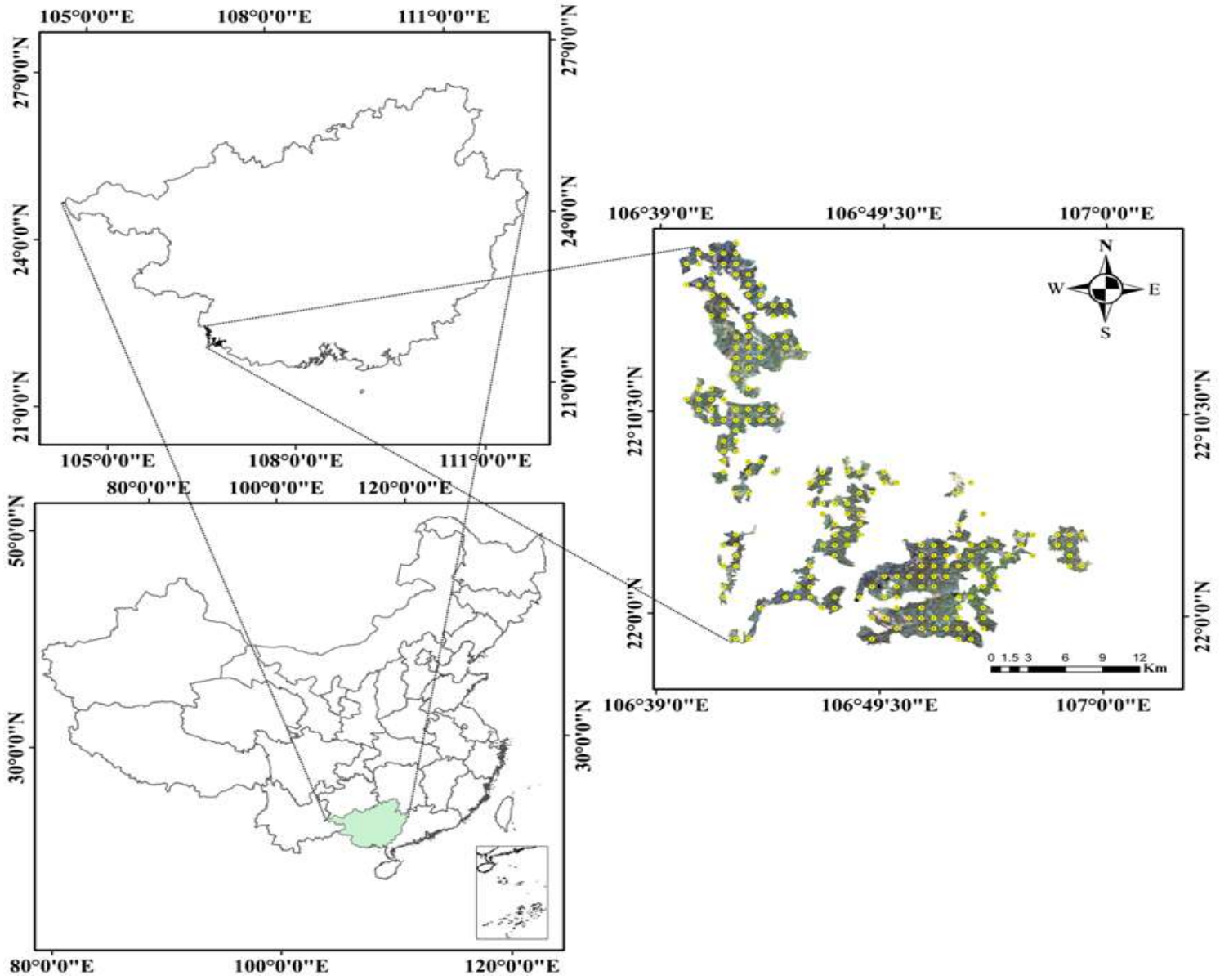
Development of SDMDs for Masson pine with the objective of **timber production** using **Reineke equation**

Masson pine (*Pinus massoniana*)

- Native Chinese, fast-growing tree species
- Distributed in a wide area of central and southern China, including northern Vietnam
- The planting area has reached **10.0 million** hm^2 and accounts for **6.7%** of all forested area in China
- The wood is of good quality and used for construction as well as the pulp and wood fiber industries

Data source

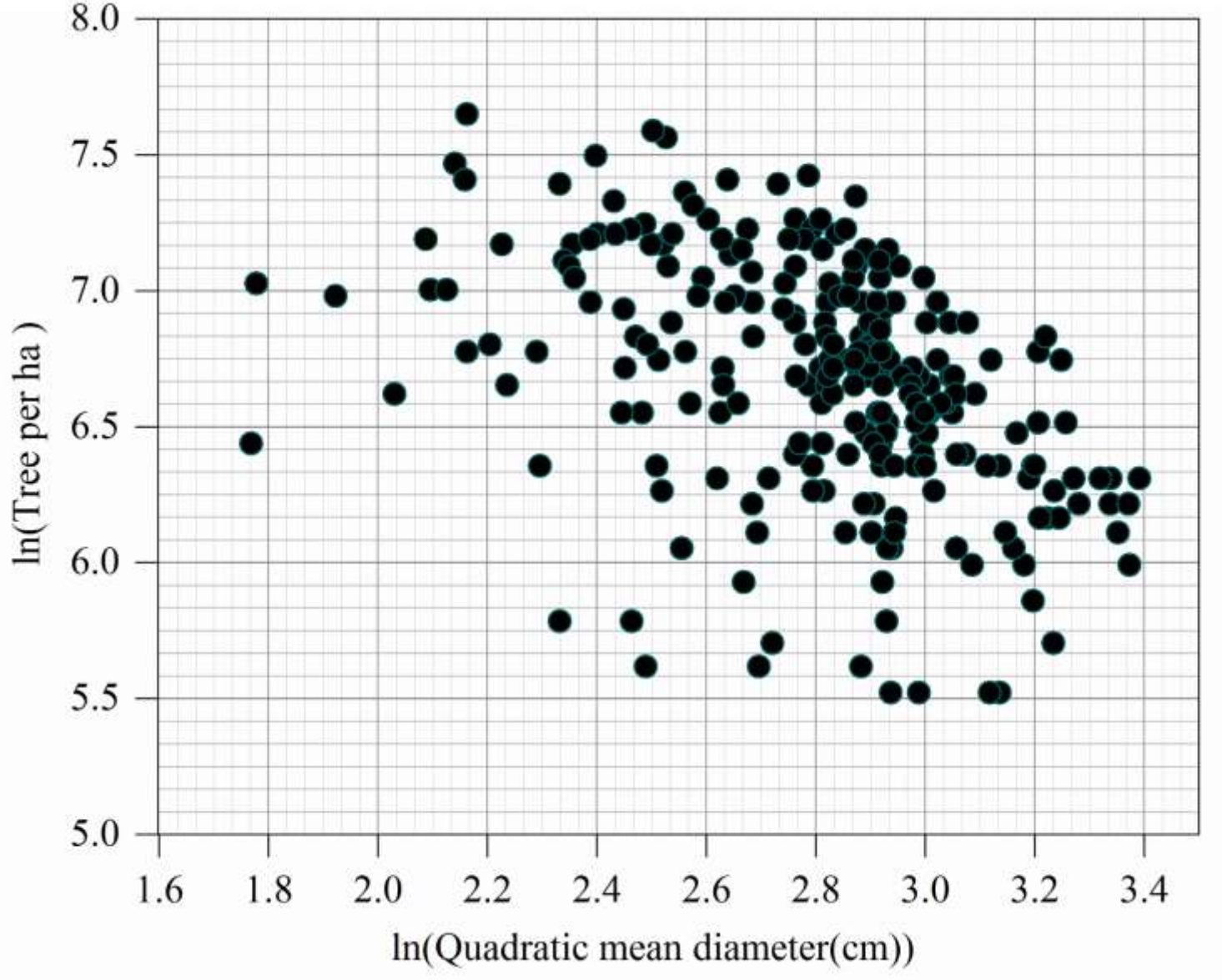
- Data from **Tropical Forest Research Center** in Guangxi Autonomous Region
- **There are 238 plots of which 90 are** Mosson Pine stands
- The plots are systematically distributed on a square grid of 1*1 km
- Dbh and tree height are measured for each tree



Reineke equation

- The equations says that, in double logarithmic scales, the relationship between tree size and stand density is a straight line in **fully stocked stands**.
- Reineke also argued that the slope of his equation is a constant value of **-1.605**

- $\boldsymbol{ln(N) = -1.605\, ln(QMD) + k}$
  - where N (trees/ha) is the number of individuals per ha, QMD (cm) the quadratic mean tree diameter

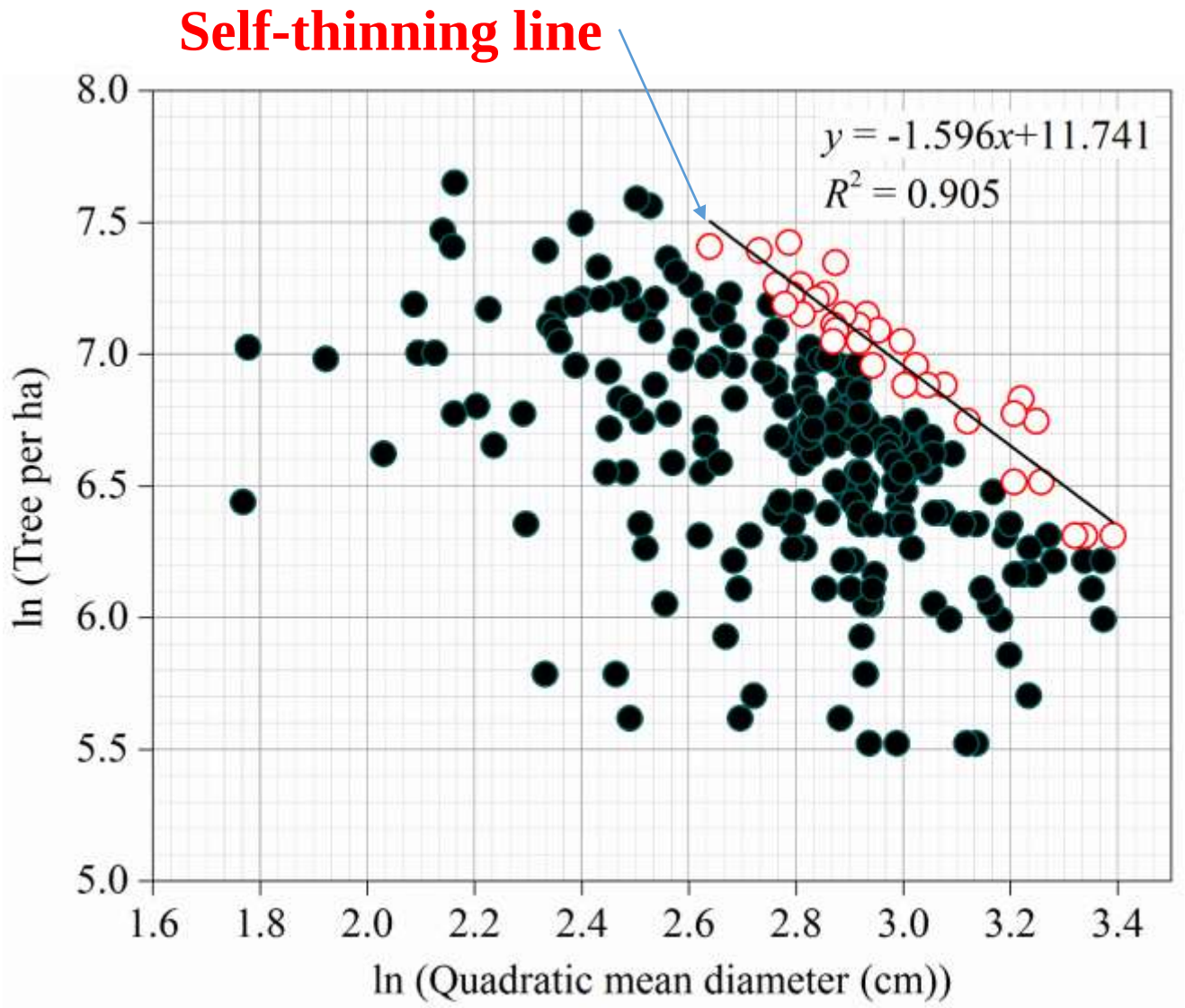

8.0
7.5
7.0
6.5
6.0
5.5
5.0
ln(Tree per ha)
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
ln(Quadratic mean diameter(cm))

Construction of SDMD

- Fully stocked plots were selected using **relative density approach**
- Reineke equation was fitted using the fully stocked plots with Reduced major axis (RMA) regression

$\ln(N)=11.741-1.596\ln(dg)$,

$R^2=0.905$



Construction of SDMD

- Based on the local experience, 60% and 30% of the self-thinning line are determined as the upper and lower limit of **optimum density interval** and 20% was defined as the reasonable value for the crown closure situation

$$\ln(N)=11.759-1.596\ln(dg) \qquad 60\%$$

$$\ln(N)=11.066-1.596\ln(dg) \qquad 30\%$$

$$\ln(N)=10.660-1.596\ln(dg) \qquad 20\%$$

SDMD for growth and harvest Prediction

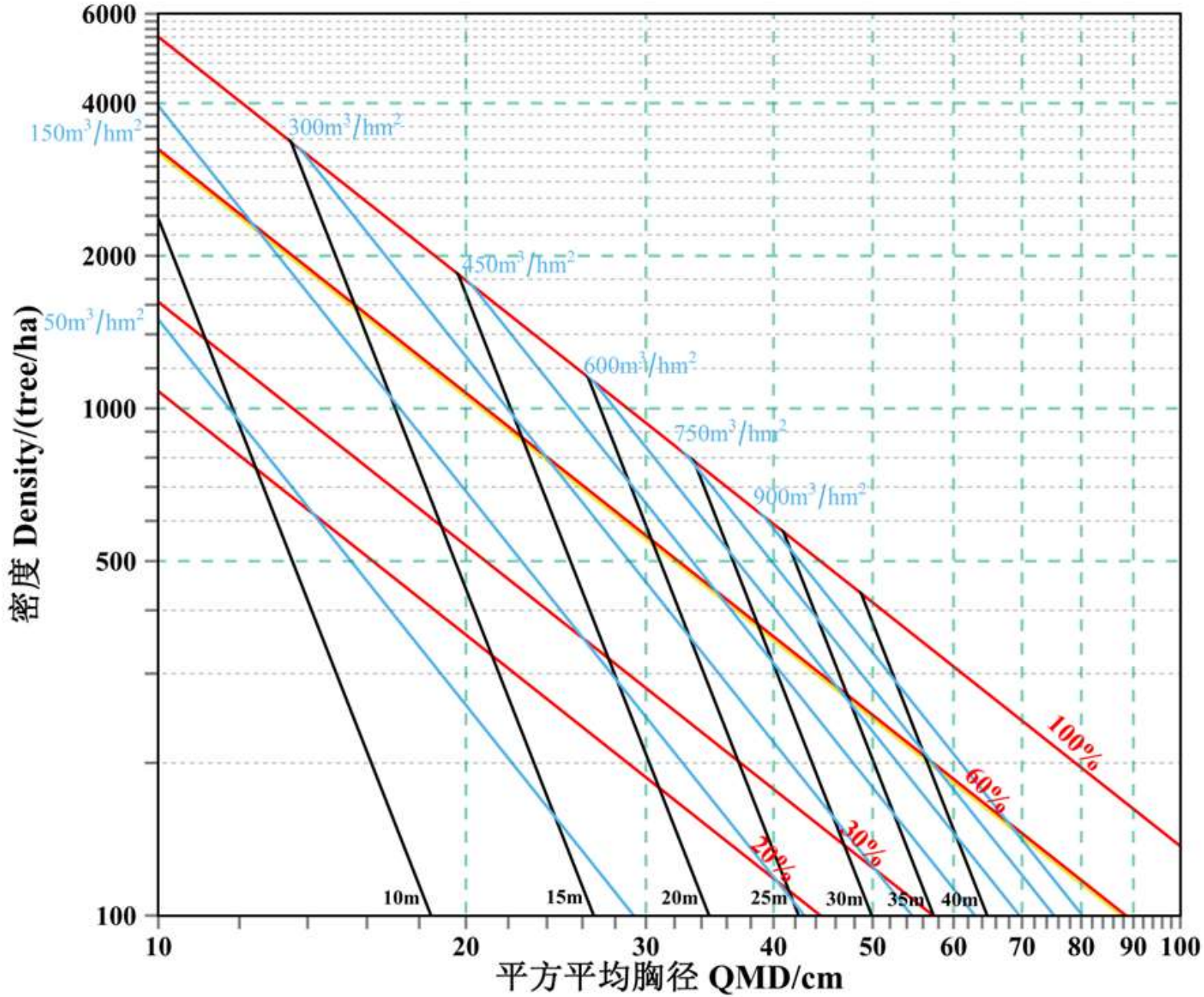
- In addition, dominate height model, stem volume model and site index model were developed to produce the final SDMD:

Dominate height model: $$H_d = 1.229 QMD^{0.869} N^{0.062}$$

Stem volume model: $$V = 0.000183 N (QMD - 1.1369)^{2.399}$$

Site index model: $$t = \frac{12.505}{0.457 + \ln\left(\frac{SI + 3}{H_d}\right)}$$

All the models were combined to construct SDMD


6000
4000
2000
1000
500
100
密度 Density/(tree/ha)
10
20
30
40
50
60
70
80
90
100
平方平均胸径 QMD/cm
150m³/hm²
300m³/hm²
450m³/hm²
50m³/hm²
600m³/hm²
750m³/hm²
900m³/hm²
100%
60%
30%
20%
10m
15m
20m
25m
30m
35m
40m

Management application 1

Simulation of different management alternatives for timber production

Management application

- Let us consider, an initial stand, in a 26 m site index class, at an index age of 20 years, with 10 cm diameter and 1662 stems per hectare
- Our target tree diameter is 40 cm
- Two management regimes are discussed: (a) a commercial thinning regime (**keep stand density in the optimum area**), (b) a precommercial thinning regime (Just for comparison)

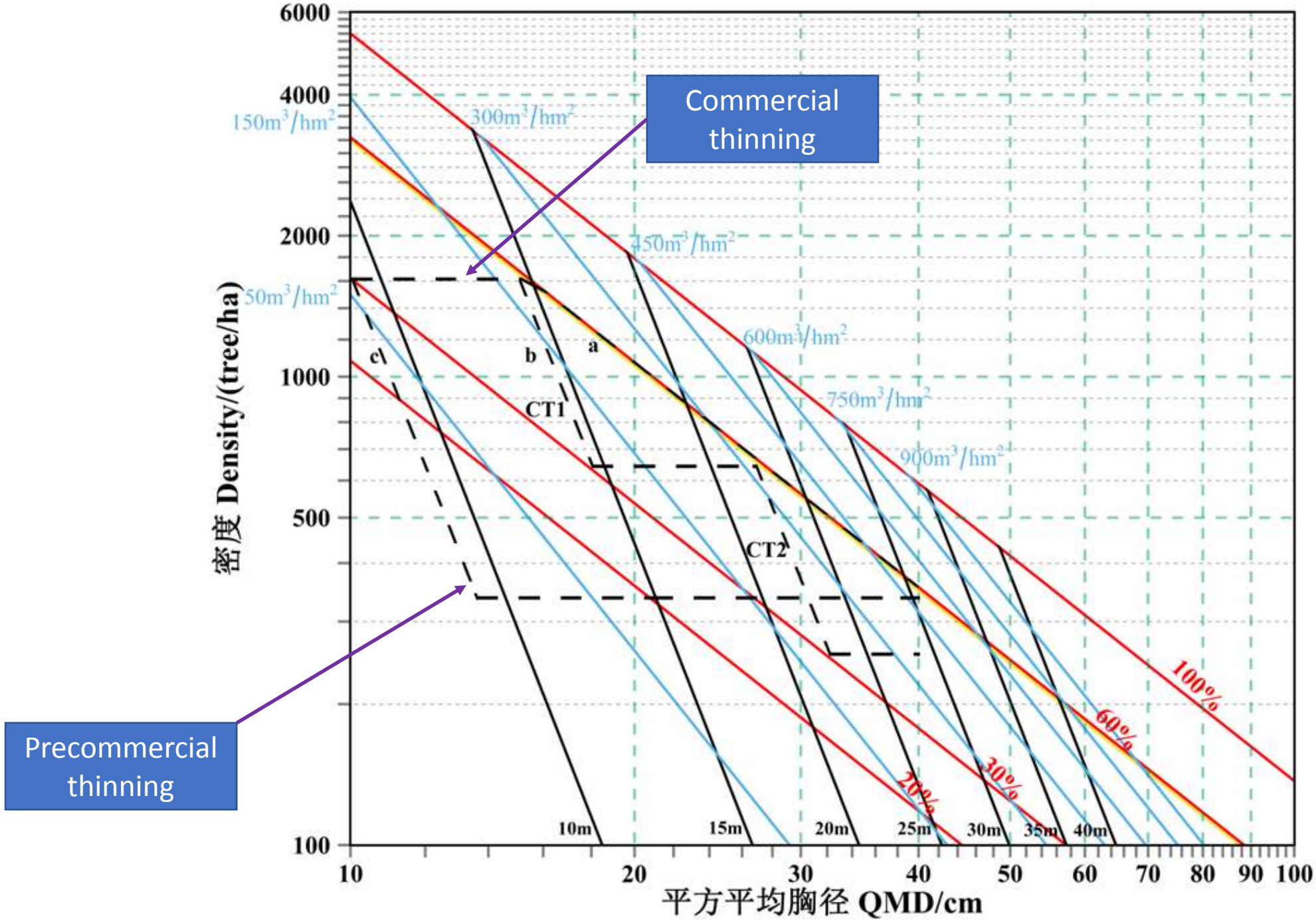

Commercial thinning
Precommercial thinning
密度 Density/(tree/ha)
平方平均胸径 QMD/cm
6000
4000
2000
1000
500
100
10
20
30
40
50
60
70
80
90
100
150m³/hm²
300m³/hm²
450m³/hm²
600m³/hm²
750m³/hm²
900m³/hm²
50m³/hm²
a
b
c
CT1
CT2
100%
60%
30%
20%
10m
15m
20m
25m
30m
35m
40m

Table 2. Comparison of two management regimes

	t (years)	hd (m)	Density (trees/ha)		Dg (cm)		V($cm^{3)}$
			before	after	before	after	
Commercial							
CT1	**14**	14.73	1622	609	15.27	18.47	79.26
CT2	**26**	23.82	609	223	28.52	34.66	158.96
Final harvest	34	27.91	223		40		305.31
Total yield							543.53
MAI							15.99
Precommercial							
CT	**9**	9.22	1622	324	10	13.67	33.11
Final harvest	41	30.25	324		40		466.2
Total yield							499.31
MAI							12.18

Both total yield and MAI in commercial thinning is larger than precommercial thinning

Part II

Development of SDMDs using **relative spacing index** for Beach sheoak with the **objective of windthrow risk reduction**

Windthrow and snow breakage

Can suitable management regimes reduce the possibility of windtrow and snow breakage?

Answer: **YES**

Slenderness coefficient (SC) : is calculated by dividing the average height by the average diameter at breast height (dbh) when both variables are measured in the same units

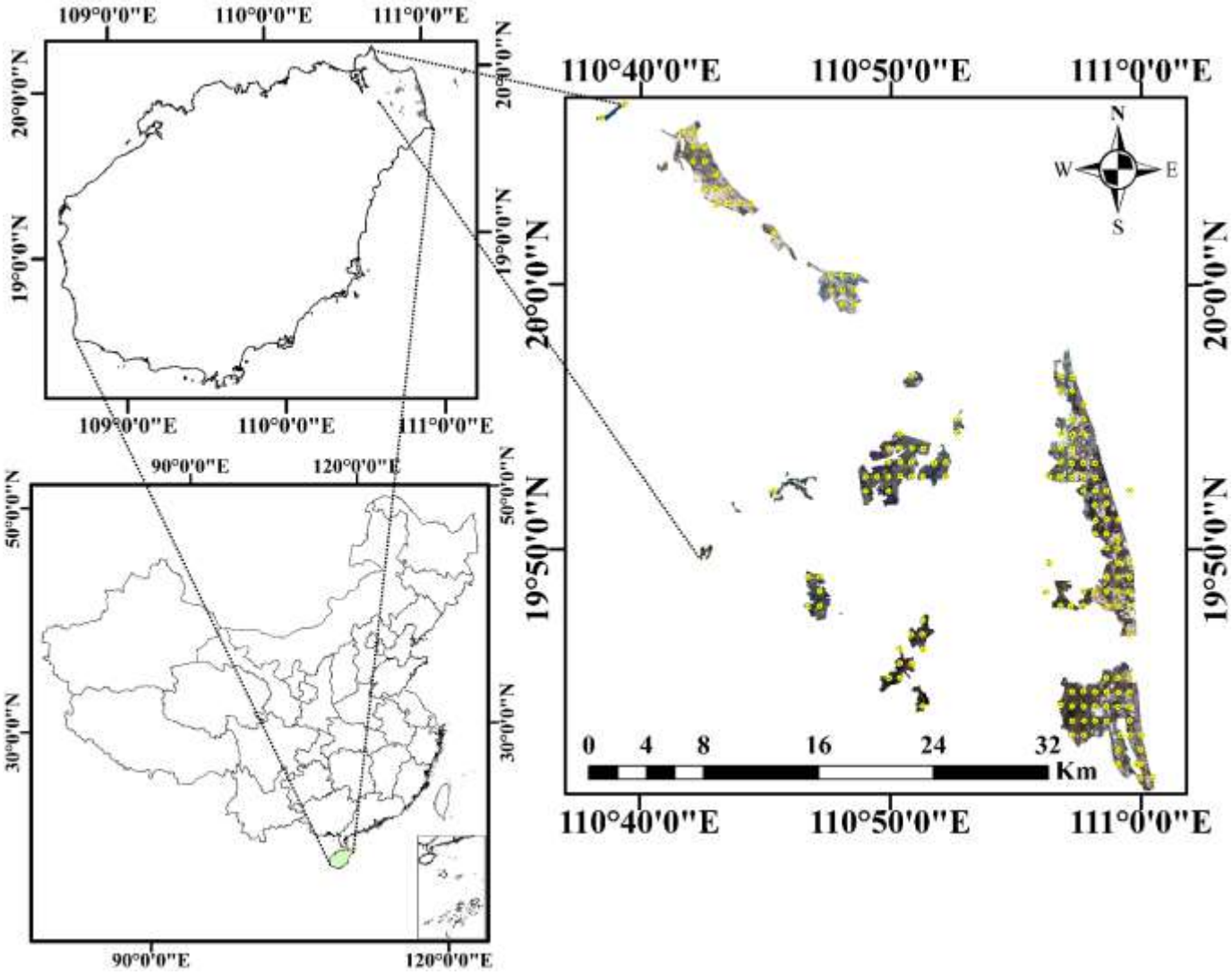
SC is closely related to stand density

Beach sheoak (*Casuarina equisetifolia*)

- Naturally distributed in South-East Asia, Australia and the Pacific
- Distinguished capability to fix atmospheric nitrogen and hence widely used to improve site quality
- An important source of fuelwood and charcoal and is also used as a building material and other wood-based industries
- One of the most popular tree species for constructing windbreaks in the sandy coastal regions throughout the world

Data source

- Data from **Daodong Forest Farm** in Hainan Province
- There are 156 plots, which are systematically distributed on a square grid of 800 × 1000 m
- The plots are cluster plots consisted of three circular subplots with a radius of 5 m
- 56 plots are dominated by Beach Sheoak
- Dbh and tree height were measured in each plot



Construction of Basic SDMD

- Basic model system for SDMD

Relative spacing index (RSI)	$RSI(\%) = \frac{10{,}000}{\sqrt{N} \cdot H_0}$
Quadratic mean diameter (QMD)	$d_g = \beta_0 \cdot N^{\beta_1} \cdot H_0^{\beta_2}$
Stand volume (SV)	V $= \beta_3 \cdot {d_g}^{\beta_4} \cdot H_0^{\beta_5} \cdot N$

Isolines

$$N = \left(\frac{10{,}000}{RS \cdot H_0}\right)^2$$

$$N = \left(\frac{d_g}{\beta_0 \cdot H_0^{\beta_2}}\right)^{\frac{1}{\beta_1}}$$

$$N = \left[\frac{V}{(\beta_3 \cdot {\beta_0}^{\beta_4}) \cdot H_0^{(\beta_2 \cdot \beta_4 + \beta_5)}}\right]^{\frac{1}{(\beta_1 \cdot \beta_4 + 1)}}$$

Construction of SDMD

- Equations for evaluation of stand stability

Relationship between the average stand height and dominant height

$$\bar{H} = \alpha_1 \cdot H_0 + \alpha_2,$$

Relationship between the average stand diameter and average stand diameter

$$\bar{D} = \alpha_3 \cdot d_g + \alpha_4$$

Equation for slenderness coefficient (SC)

$$SC = \frac{\alpha_1 \cdot H_0 + \alpha_2}{\alpha_3 \cdot \beta_0 \cdot N^{\beta_1} \cdot H_0^{\beta_2} + \alpha_4}$$

Isoline for SC

$$N = \left(\frac{\alpha_1 \cdot H_0 + \alpha_2 - \alpha_4 \cdot SC}{\alpha_3 \cdot \beta_0 \cdot H_0^{\beta_2} \cdot SC} \right)^{\frac{1}{\beta_1}}$$

Table 2 Regression coefficients of the models predicting the stand variables for const

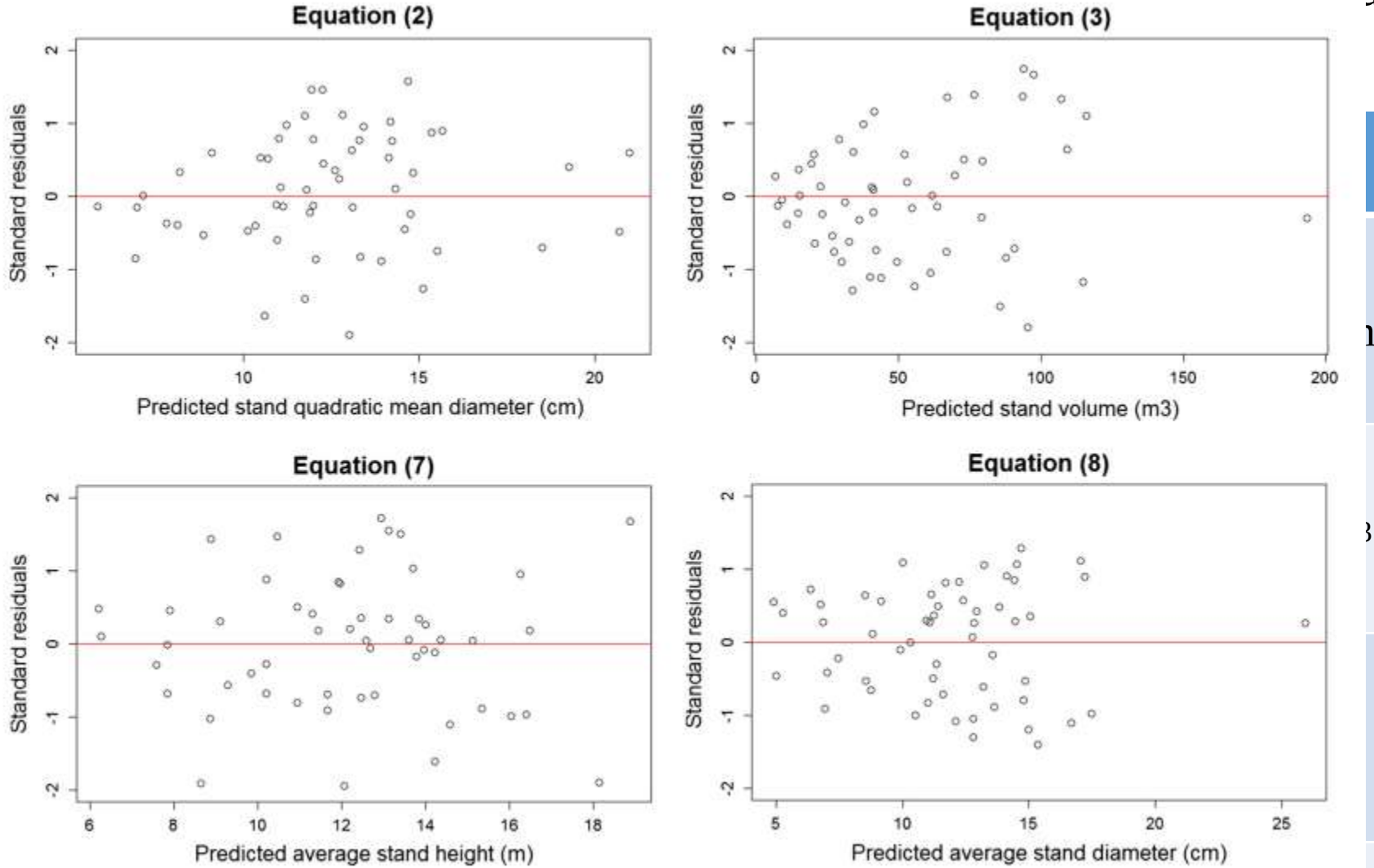
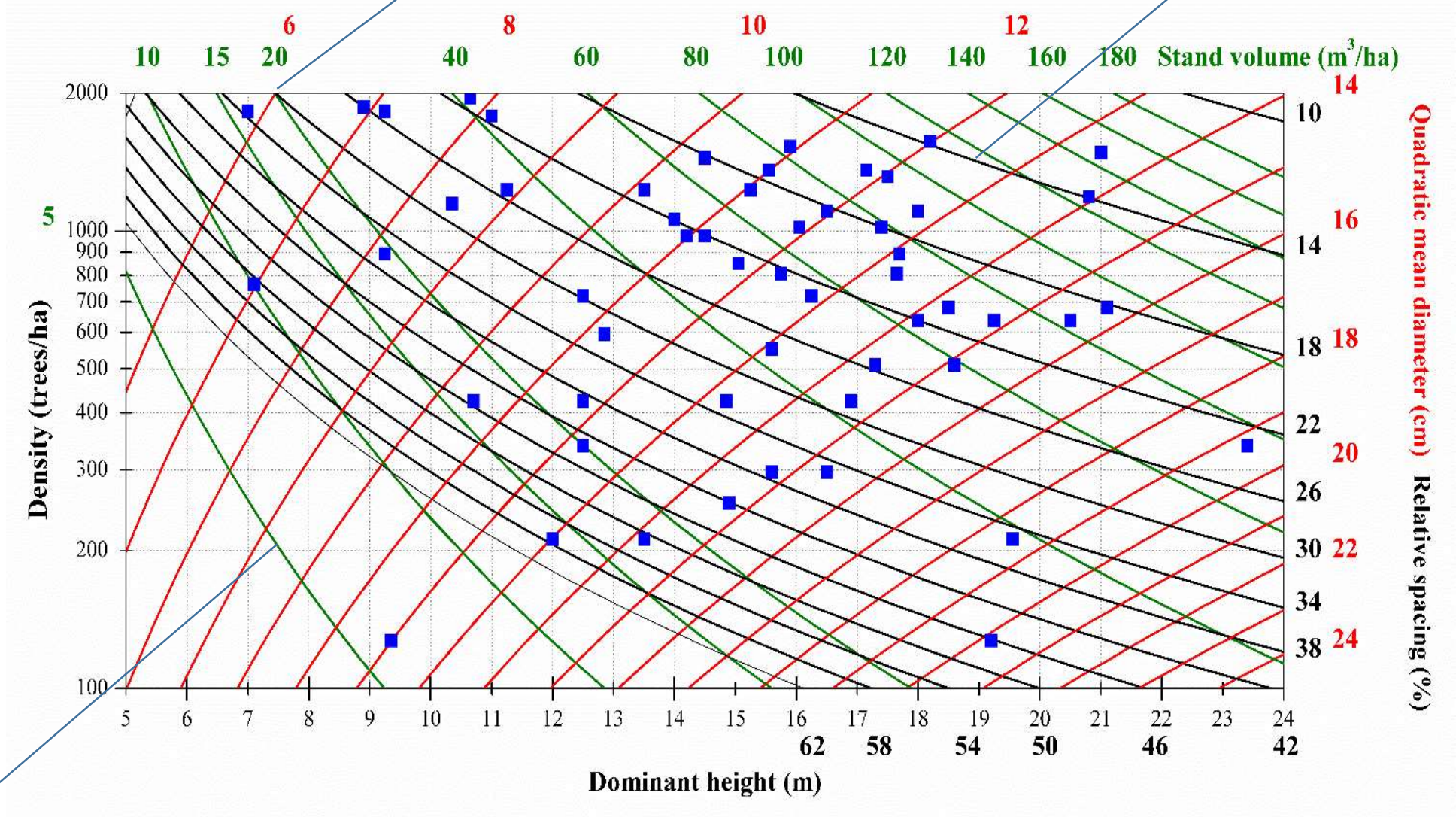


Fig. 2 Plots of standardized residuals against the fitted values of the models used to produce the basic SDMD

Equation						P
2						<0.001
3						<0.001
7						<0.001
8	(0.0099)	(0.0212)		0.98	0.280 cm	<0.001

Isoline for QMD

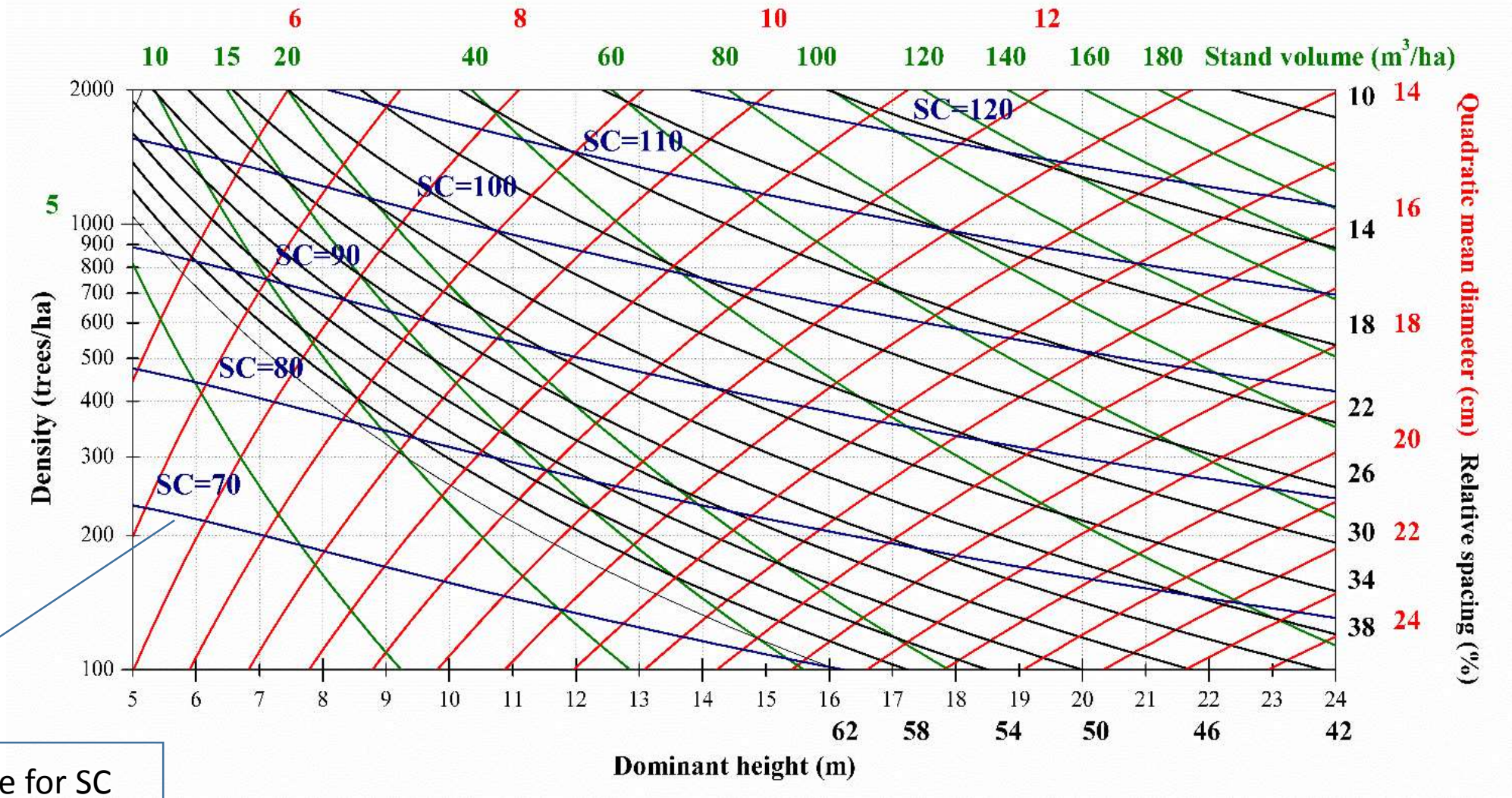
Isoline for relative spacing



Isoline for stand volume

Basic SDMD

We superimposed isolines for SC on the Basic SDMD

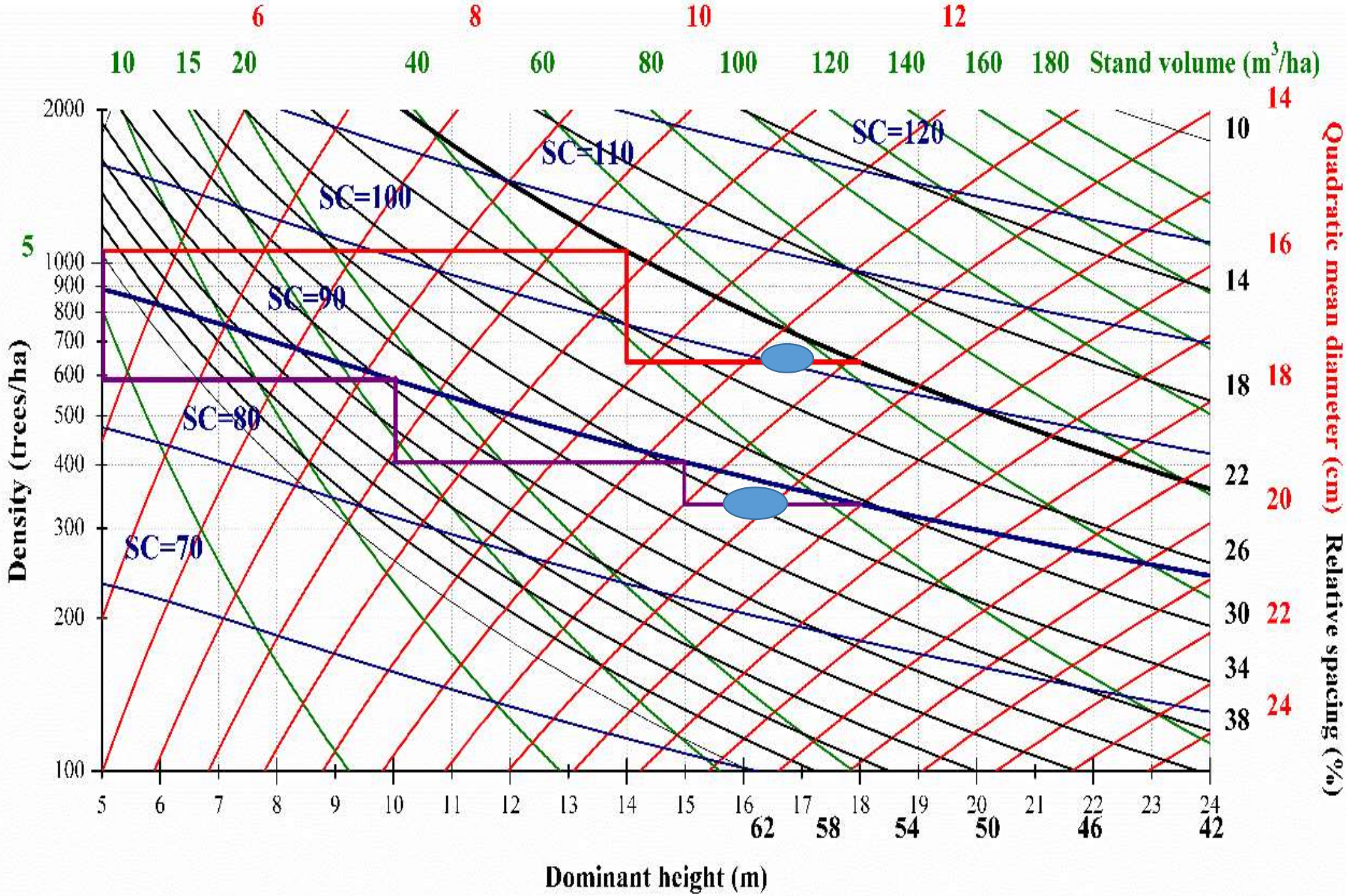


Isoline for SC

SDMD capable of stand stability assessment

Management application

- Let us consider, for example, an initial stand in a 5-m site class at an index age of 3 years, with 10 cm diameter and a density of 1054 trees per hectare.
- We evaluated the following two management regimes to reach the same target harvest (target harvest height 18m):
  - a commercial thinning;
  - a commercial thinning **considering stand stability represented by the SC**


6
8
10
12
10 15 20 40 60 80 100 120 140 160 180 Stand volume (m3/ha)
2000
1000
900
800
700
600
500
400
300
200
100
5
SC=120
SC=110
SC=100
SC=90
SC=80
SC=70
Density (trees/ha)
14
16
18
20
22
24
10
14
18
22
26
30
34
38
Quadratic mean diameter (cm) Relative spacing (%)
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
62 58 54 50 46 42
Dominant height (m)

(2) A commercial thinning without considering stand stability

	t	H_0	N (trees/ha)		dg (cm)		SC		V
	(years)	(m)	before	after	before	after	before	after	(m^3/ha)
Thinning without consideration of stand stability									
TH1	7	14	1054	638	10.70	11.78	106	97	13.50
Final harvest	14	18	638		14.13		102		63.21
Total yield									76.71
MAI									5.48

Only one intermediate thinning operations should be conducted, with a yield of 76.71 m^3/ha

(1) A commercial thinning with considering stand stability

	t	H_0	N (trees/ha)		dg (cm)		SC		V
	(years)	(m)	before	after	before	after	before	after	(m^3/ha)
Thinning with consideration of stand stability									
TH1	3	5	1054	589	5.09	5.69	93	90	1.76
TH2	5	10	589	405	9.38	10.08	90	86	3.59
TH3	8	15	405	335	13.51	14.01	90	88	3.61
Final harvest	14	18	335		15.98		90		42.57
Total yield									51.53
MAI									3.68

To secure stand stability, **THREE** intermediate thinning operations should be conducted, with a yield of 51.53 m^3/ha which is less than 76.71 m^3/ha in the first management regime.

Conclusion

- The current plantation management regimes with fixed rotation lengths and rigid thinning schedules might fail in achieving management objective
- SDMD can simulate different management alternatives in various site qualities for different objectives
- More SDMDs should be constructed for the most commonly tree species in China

Thank you for your attention !!!