Developing a Site Productivity Map Based on Continuous Forest Inventory Data

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Forest Biometrics Research Institute

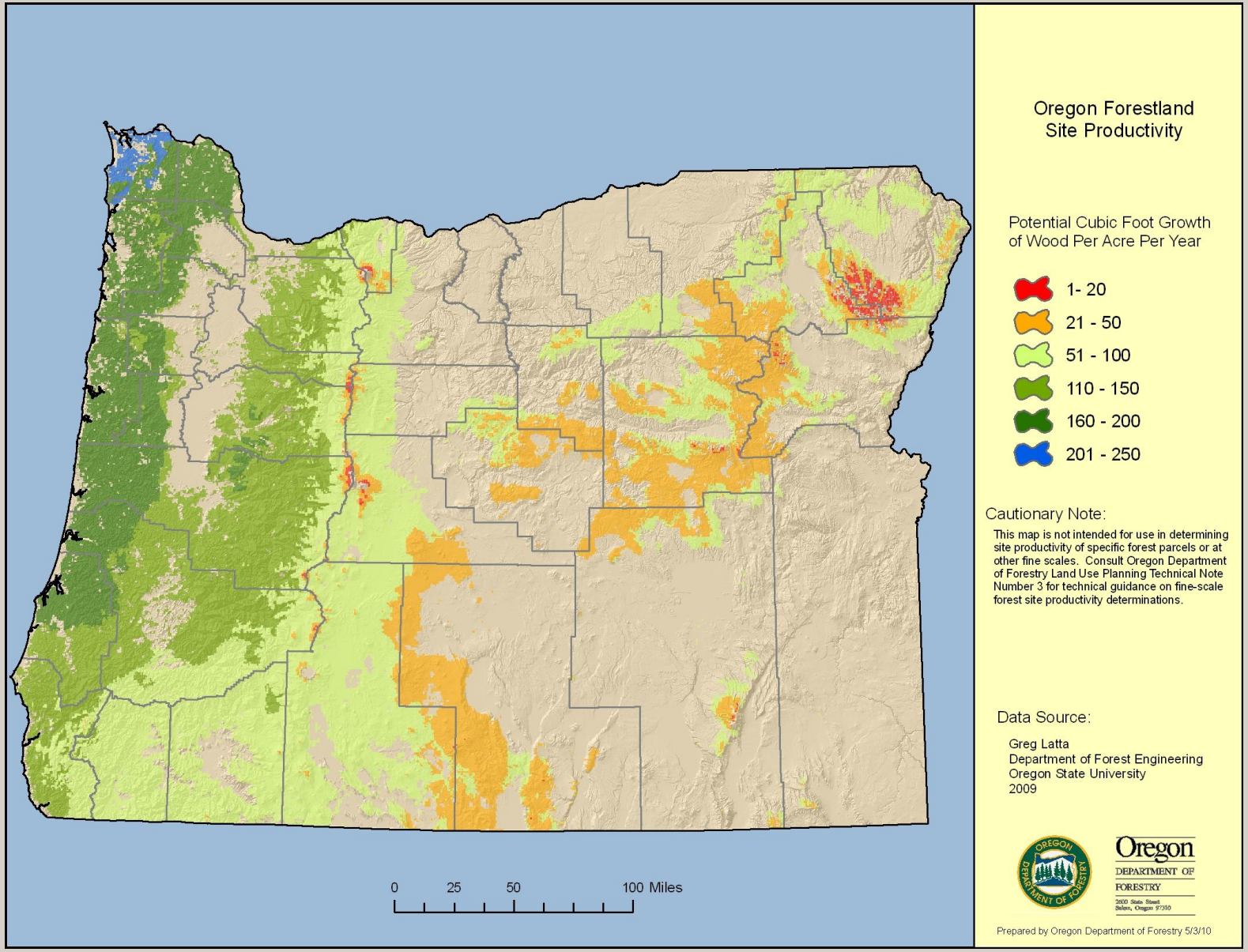
Forest Biometrics Research Institute (FBRI)
Overview of the Institute

- FBRI is a 501(c)(3) nonprofit organization founded by Dr. Jim Arney in 2002
- The Forest Projection & Planning System (FPS) is the Institute's flagship software program
  - A combination of forest inventory, growth & yield, and harvest scheduling applications embedded within Microsoft Access
- 70+ member organizations financially support FBRI
- FBRI's Mission: Provide FPS to member organizations to assist them with forest inventory, growth & yield projections, and forest planning
- FBRI has a five-member Board of Directors
  - Ken Borchert, Chairman, Bureau of Indian Affairs
  - Bruce Ripley, University of Idaho
  - Brian Sharer, Finite Carbon
  - Marc Vomocil, Starker Forests Inc.
  - David Walters, Green Diamond Resource Company
- Web site: https://forestbiometrics.org/

Forest Biometrics Research Institute

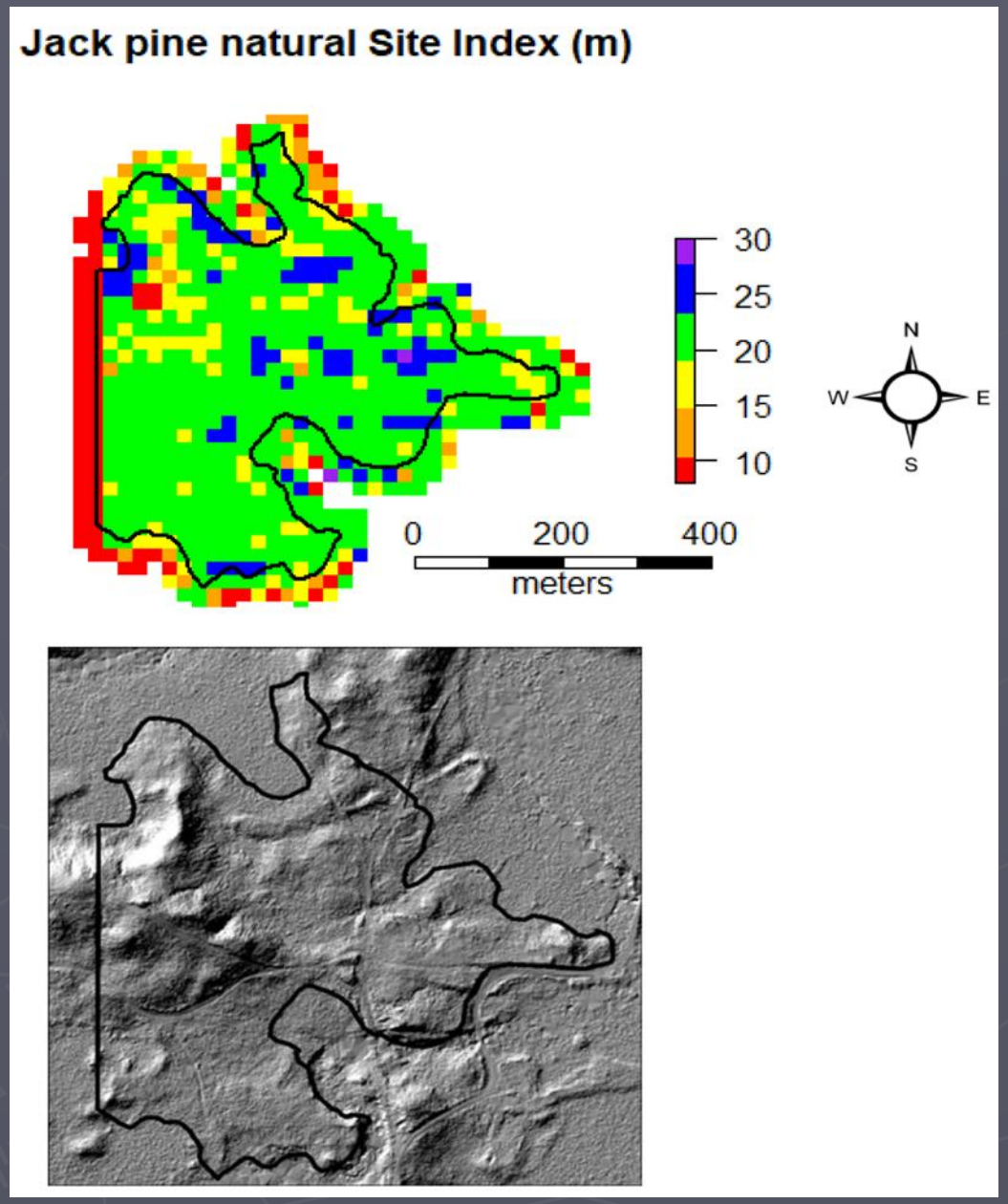
Things to be Discussed Today

- Developing a Site Productivity Map Based on Continuous Forest Inventory (CFI) Data
  - Six Steps:
    1. Determine the site index of "site trees" using repeat CFI height measurements on individual trees
    2. Assign a site index to each CFI plot
    3. Develop a model to predict site index from environmental variables such as elevation, precipitation, solar radiation, and soil depth
    4. Apply the model to every acre of the subject property
    5. Calculate the average site index for each forest stand and make a site productivity map for the property
    6. Review the model, look for weaknesses, make incremental improvements if needed



Site Productivity Maps

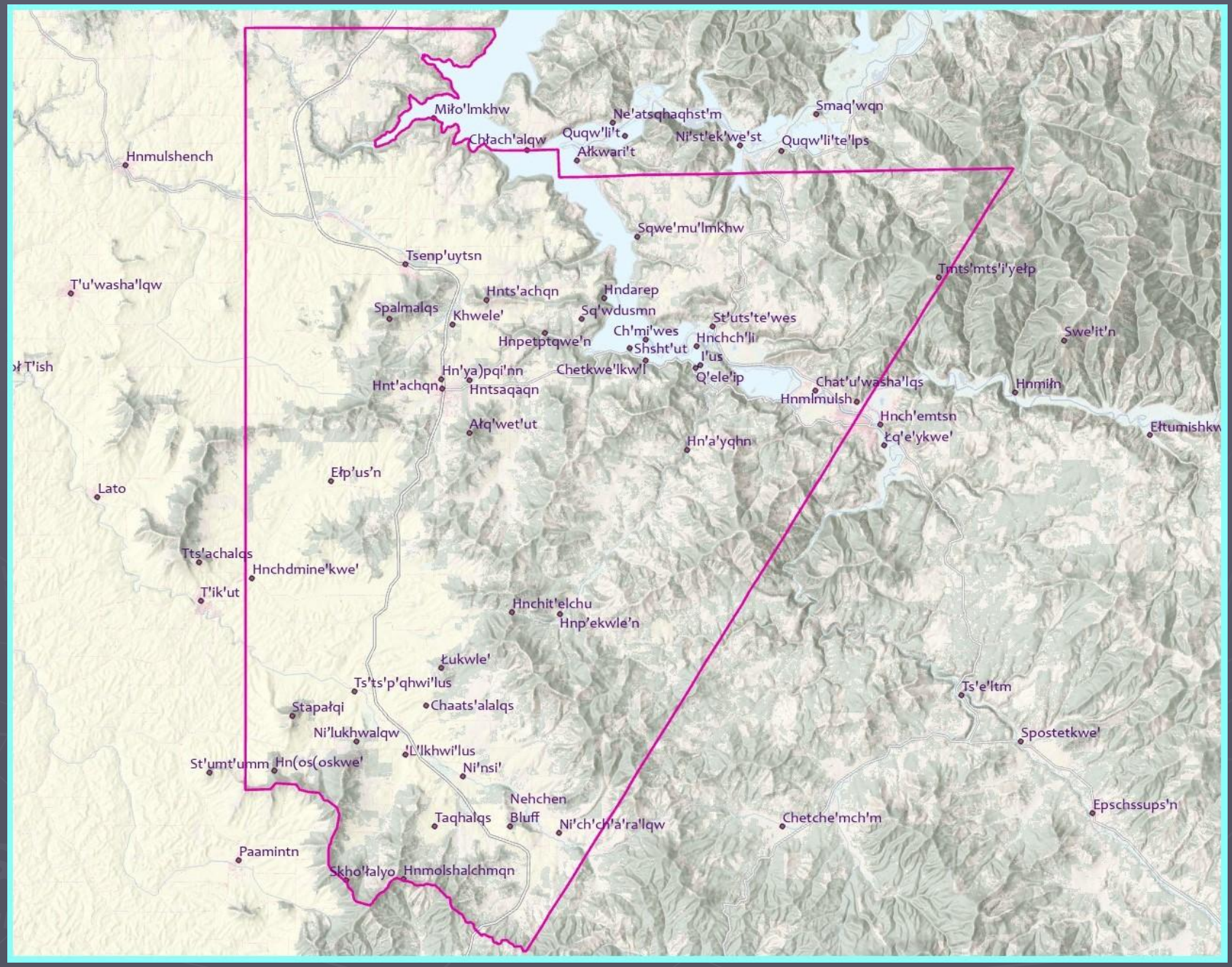
- This is a good example of a small-scale site productivity map



Source: *Assessing Site Productivity via Remote Sensing—Age-Independent Site Index Estimation in Even-Aged Forests by Penner et al. (2023)*

Site Productivity Maps

- This is a good example of a **large-scale** site productivity map
- This is the scale at which we desire to apply the site index models developed during this project



Project Area

Coeur d'Alene Reservation in Northwestern Idaho

Step 1: Determine the site index of "site trees" using repeat CFI height measurements on individual trees

- Literature review – The following references use repeat height measurements to calculate site index
  - Direct and indirect site index determination for Norway spruce and Scots pine using bitemporal airborne laser scanner data by Noordermeer et al. (2018)
  - Age-independent site index mapping with repeated single-tree airborne laser scanning by Solberg et al. (2019)
  - Assessing Site Productivity via Remote Sensing—Age-Independent Site Index Estimation in Even-Aged Forests by Penner et al. (2023)
  - A New FBRI Enterprise Service: Estimation of Site Index Using Repeat Lidar Data by Opalach (2023) – https://forestbiometrics.org/fbri/enterprise-services/
  - A growth-effective age-based periodic site-index for the estimation of dynamic forest site productivity under environmental changes by Yue et al. (2024)

Step 1: Determine the site index of "site trees"… (continued)

- Literature review – Fig. 1 is from Yue et al. (2024)
  - Yue et al. (2024) describe a method for determining site index based on repeat measurement data: H_t, H_{t-1}, and p (the interval length between two successive measurements $A_t - A_{t-1}$)
  - To be clear, the Yue et al. (2024) method does not require breast height age !!! Just the interval length p !!!

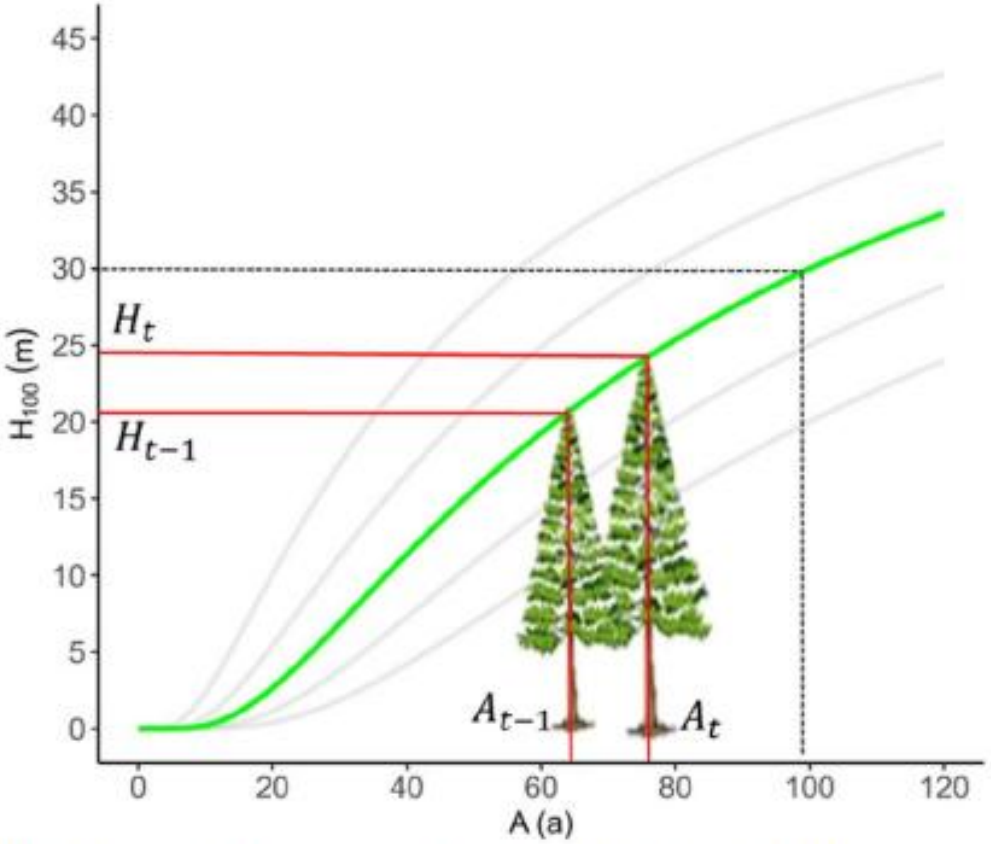
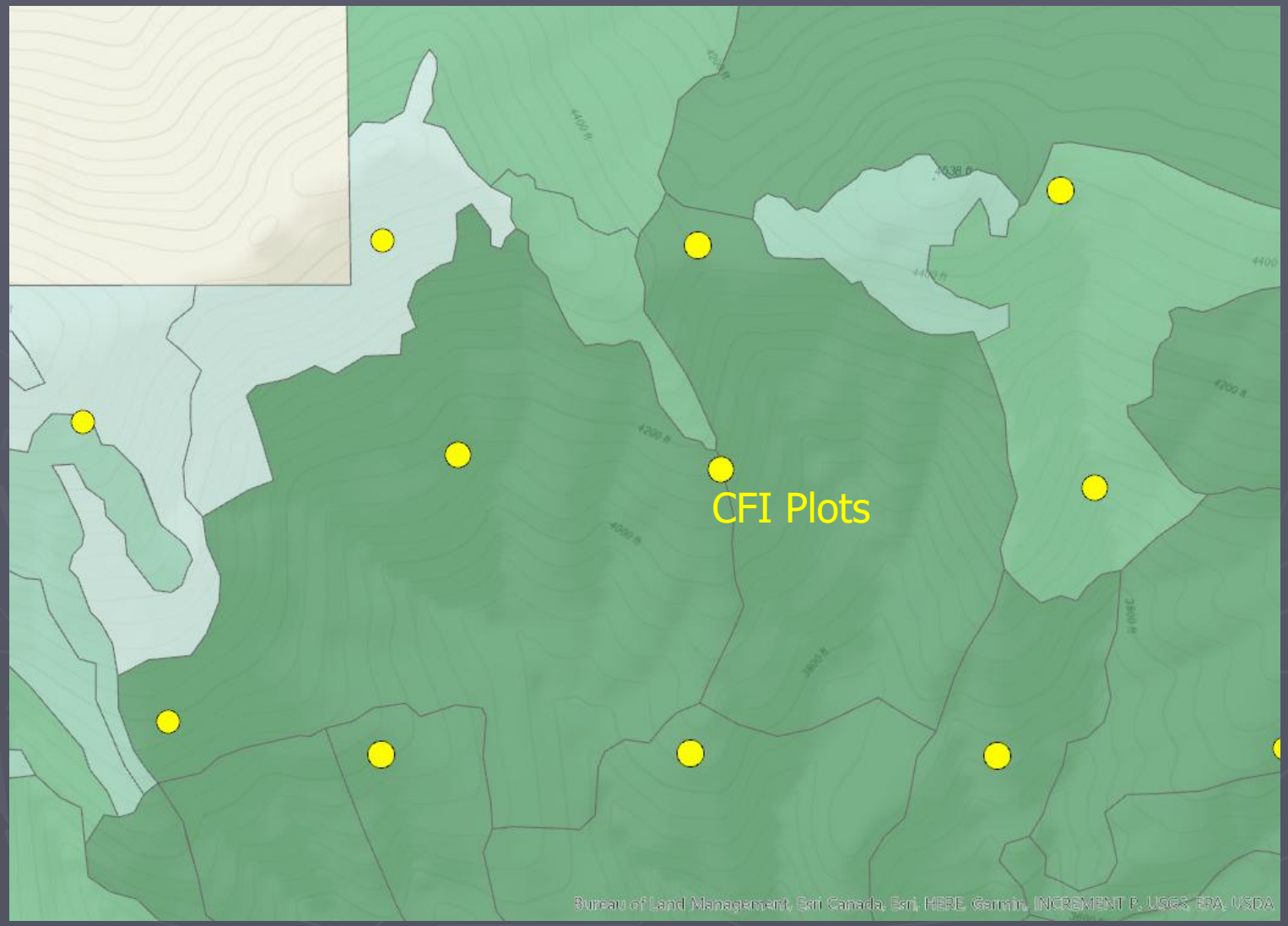


Fig. 1 Example of a stand dominant height-age model (H_{100}: stand dominant height, A: stand age, t: number of the survey). The green curve corresponds to a site index of 30 (m) at base age 100 years

Step 1: Determine the site index of "site trees"… (continued)



CFI Plots

- Systematically installed across the Tribe's forest land
- Plots are ¼-acre in size
  - Tree heights were subsampled and only measured in the NE quadrant of the plot
- First measurements taken in 1978
- Plots were measured a total of 5 times with the last measurement occurring in 2019
- That's over 40 years of growth data !!!
- There are hundreds of plots

Step 1: Determine the site index of "site trees"... (continued)

PlotMeasurements

PlotMeasKey	PlotKey	PeriodNu	PlotSta
P000012-03	P000012	3	
P000012-04	P000012	4	
P000012-05	P000012	5	
P000013-01	P000013	1	
P000013-02	P000013	2	
P000013-03	P000013	3	
P000013-04	P000013	4	
P000013-05	P000013	5	
P000014-01	P000014	1	
P000014-02	P000014	2	
P000014-03	P000014	3	
P000014-04	P000014	4	
P000014-05	P000014	5	
P000015-01	P000015	1	
P000015-02	P000015	2	
P000015-03	P000015	3	
P000015-04	P000015	4	
P000015-05	P000015	5	
P000016-01	P000016	1	
Total			

Record: 66 of 3355 No Filter Search

TreeMeasurements

TreeMeasKey	TreeKey	TreeHistory	IDBH	BDFTDefect	TotalHeight	Problem
P000013-0001-04	P000013-0001	0	265	15	89	
P000013-0002-04	P000013-0002	0	142		76	
P000013-0003-04	P000013-0003	0	199		89	
P000013-0012-04	P000013-0012	0	239		99	
P000014-0001-04	P000014-0001	0	217		97	
P000014-0002-04	P000014-0002	0	165	3	92	
P000014-0003-04	P000014-0003	0	269		108	
P000014-0004-04	P000014-0004	0	273	0	100	
P000014-0019-04	P000014-0019	0	78		52	
P000014-0020-04	P000014-0020	0	159	2	92	
P000014-0022-04	P000014-0022	0	123	2	60	
P000014-0023-04	P000014-0023	0	131	15	73	
P000015-0002-04	P000015-0002	0	193	4	116	
P000015-0003-04	P000015-0003	0	226	5	112	
P000015-0004-04	P000015-0004	0	168	2	112	
P000015-0006-04	P000015-0006	0	266		114	
P000015-0022-04	P000015-0022	0	166	2	110	
P000015-0024-04	P000015-0024	0	159		104	
P000015-0025-04	P000015-0025	0	170	2	78	

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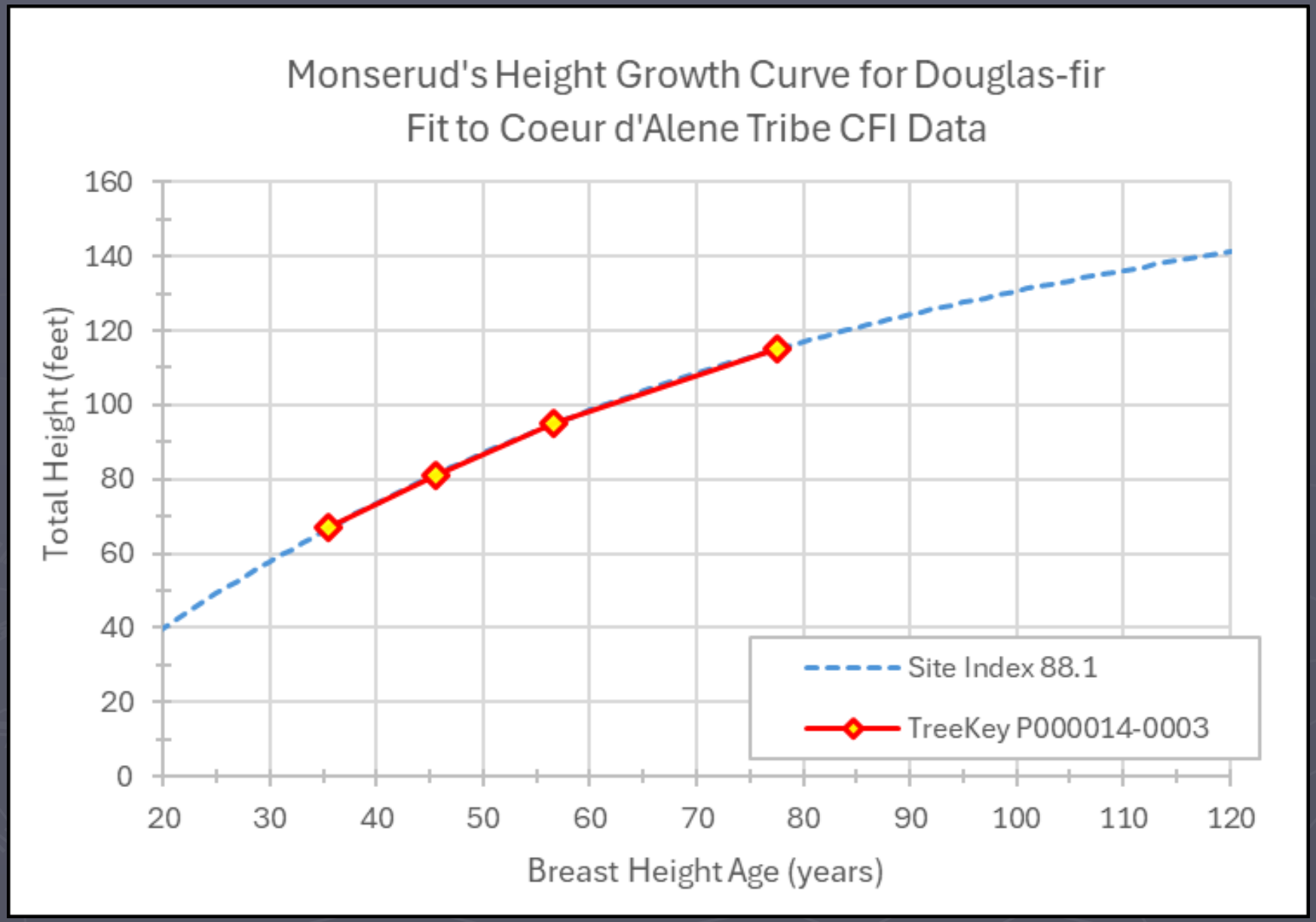
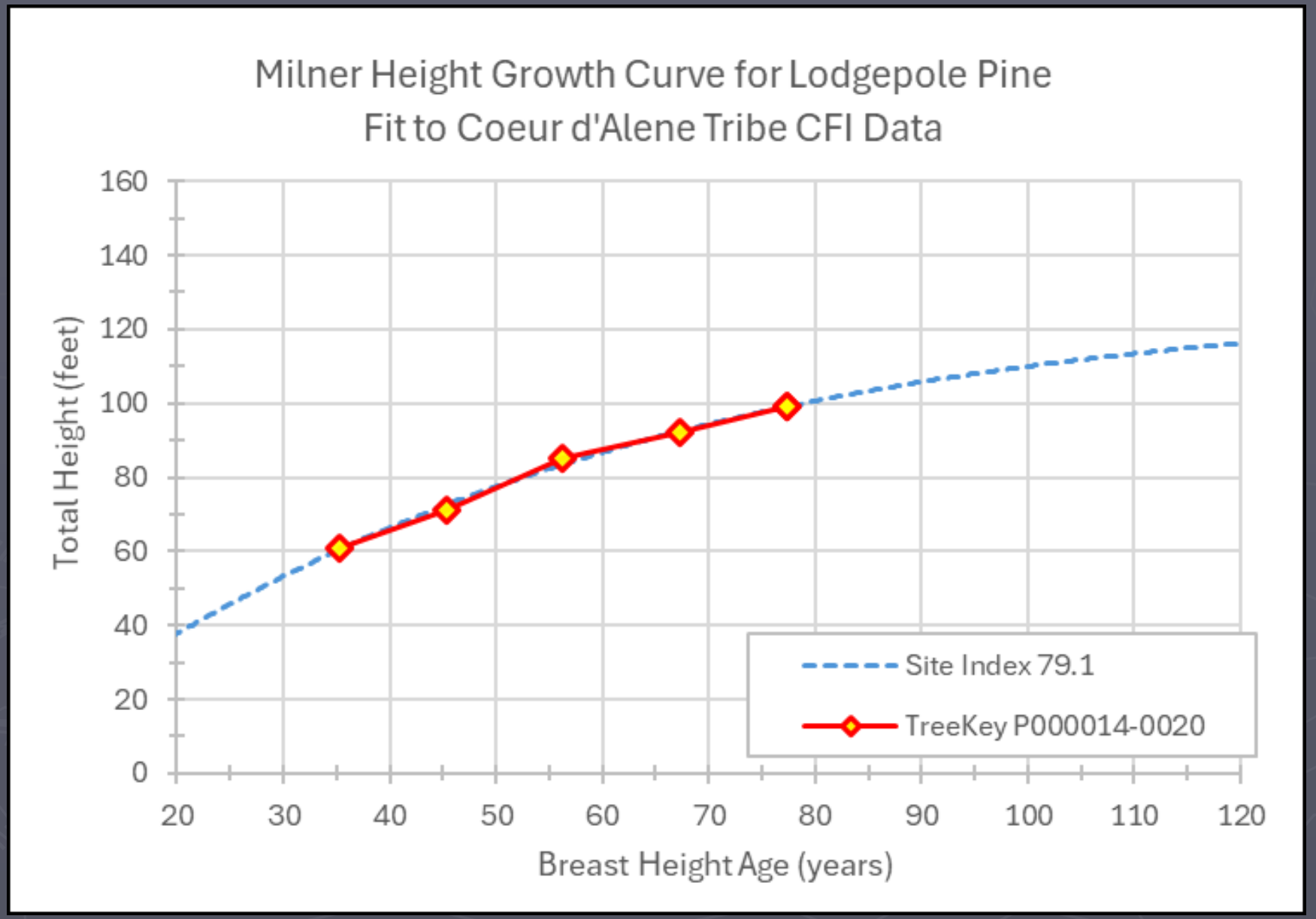
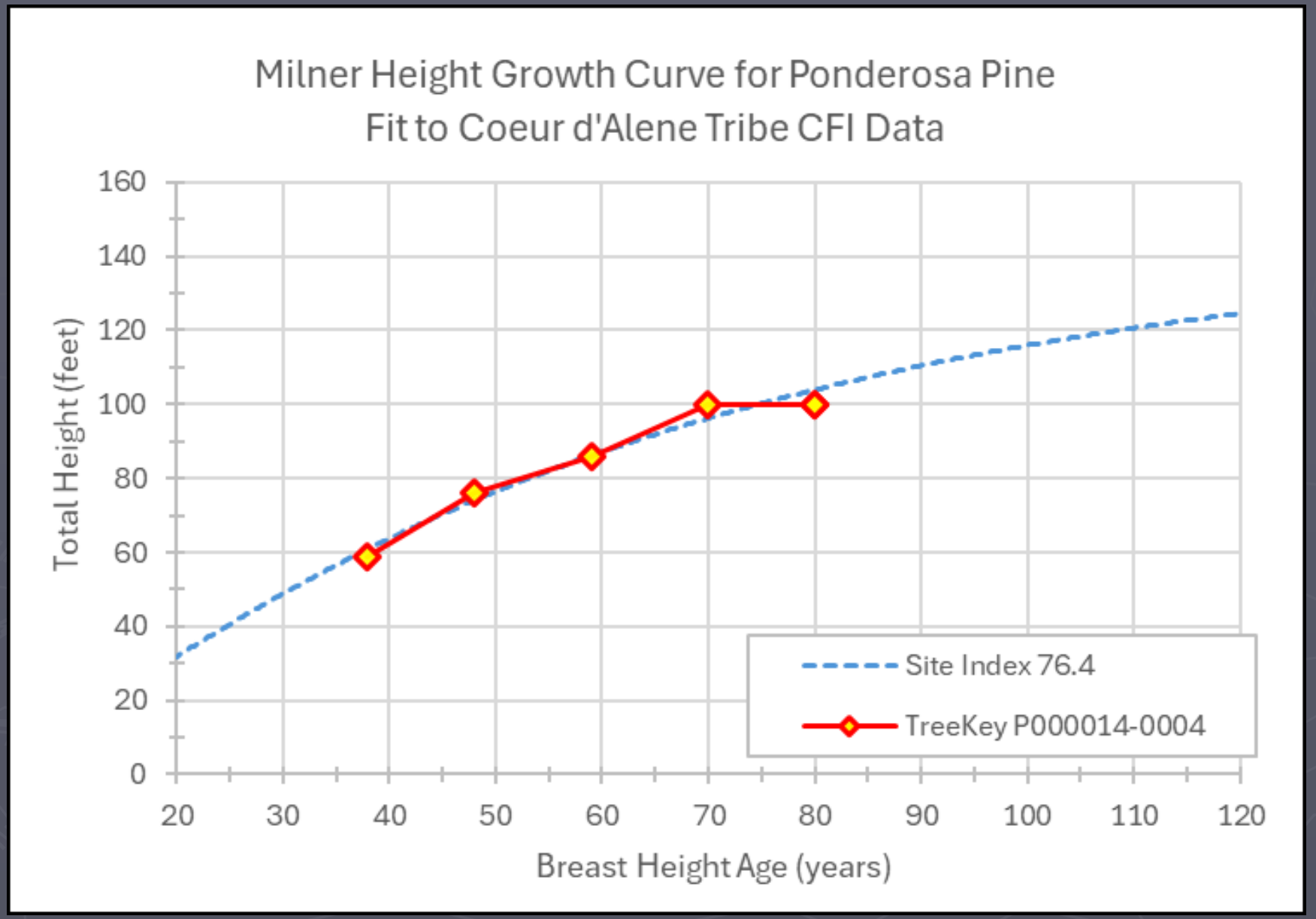


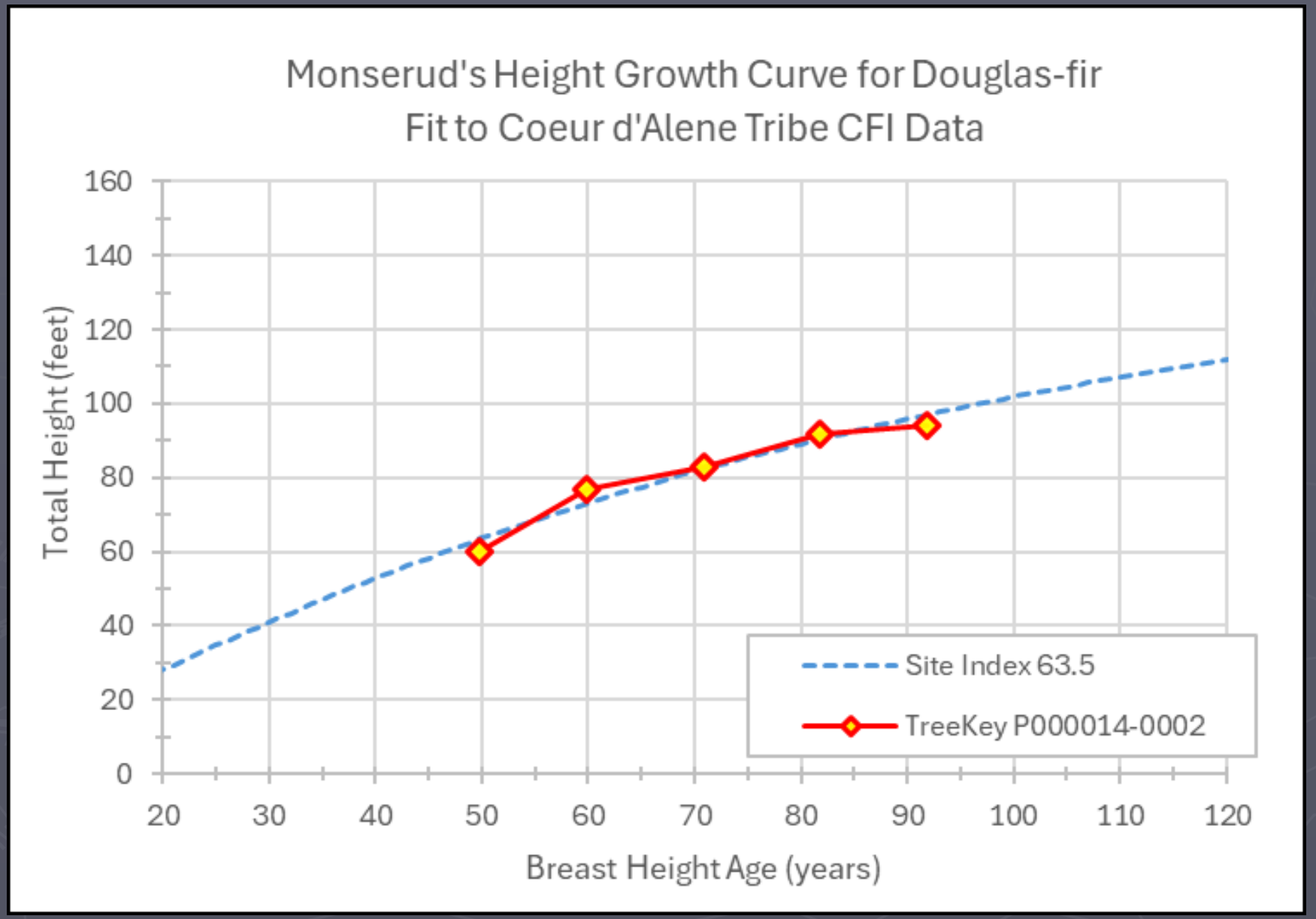
CFI Plot 14
Tree 3
Douglas-fir



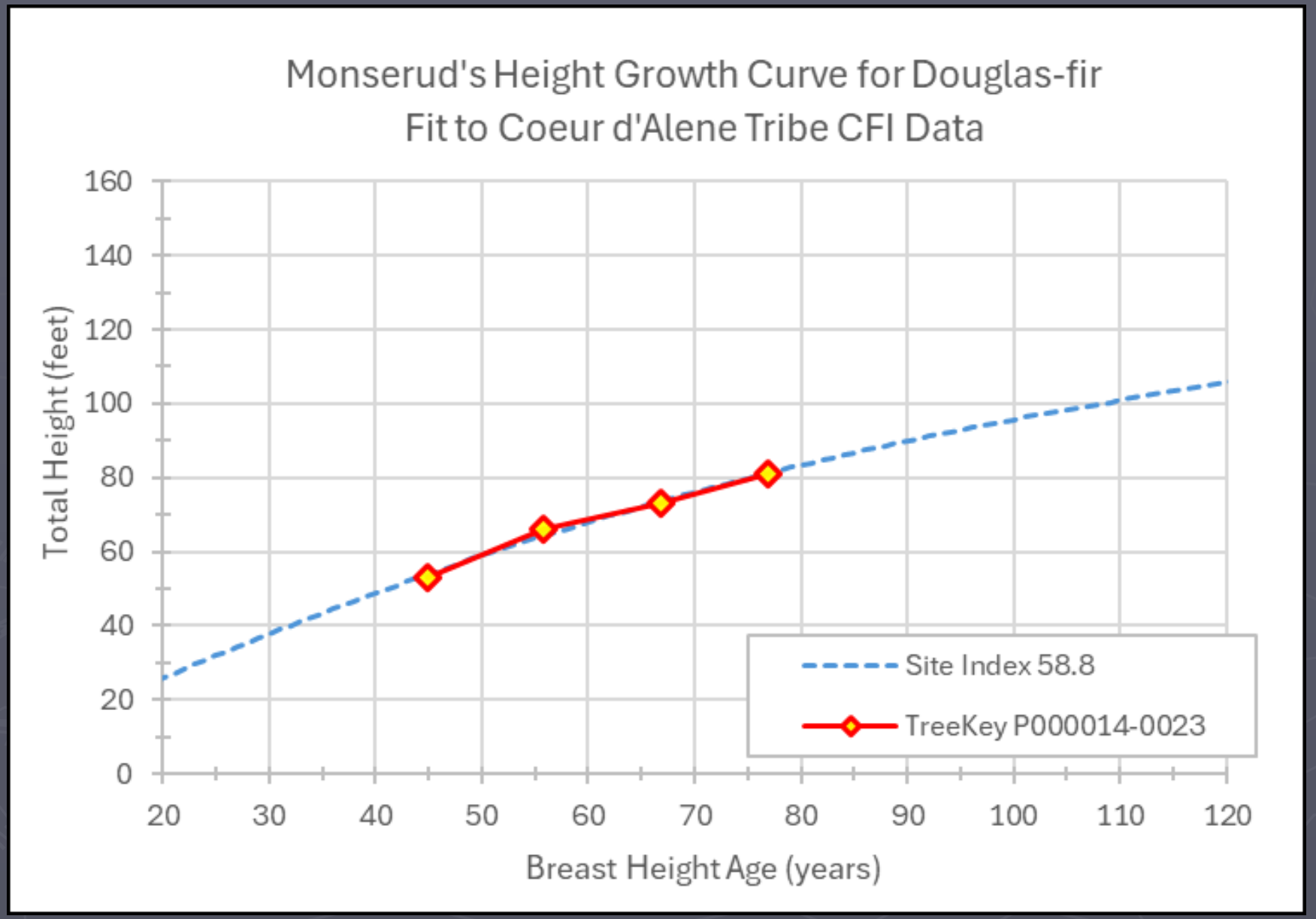
CFI Plot 14
Tree 20
Lodgepole Pine



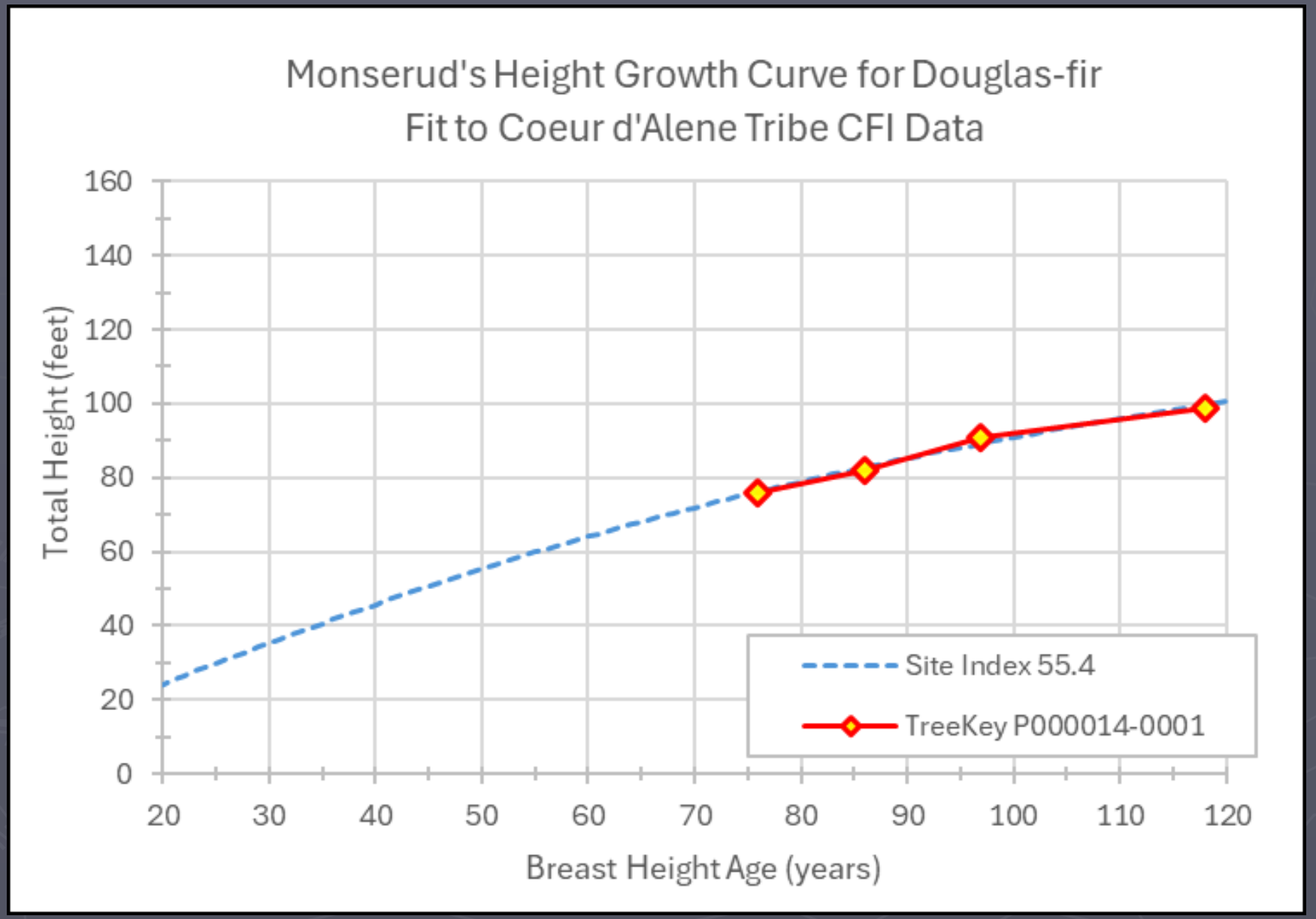
CFI Plot 14
Tree 4
Ponderosa Pine



CFI Plot 14
Tree 2
Douglas-fir



CFI Plot 14
Tree 23
Douglas-fir



CFI Plot 14
Tree 1
Douglas-fir

Step 2: Assign a site index to each CFI plot

CFI Plot 14

- The site index for CFI Plot 14 is the average site index of the three fastest growing trees: DF088, LP079, and PP076 is 81 feet
- CFI Plot 14 site index is (88+79+76)/3 ≈ 81 feet
- If a CFI plot had seven or more trees, the site index of the plot was based on the average of the three fastest growing trees

Step 2: Assign a site index to each CFI plot (continued)

CFI Plot 20

- The site index for CFI Plot 20 is the average site index of the three fastest growing trees: GF068, GF063, and DF060 is 63 feet
- CFI Plot 20 site index is (68+63+60)/3 ≈ 63 feet
- If a CFI plot had seven or more trees, the site index of the plot was based on the average of the three fastest growing trees

Step 2: Assign a site index to each CFI plot (continued)

CFI Plot 42

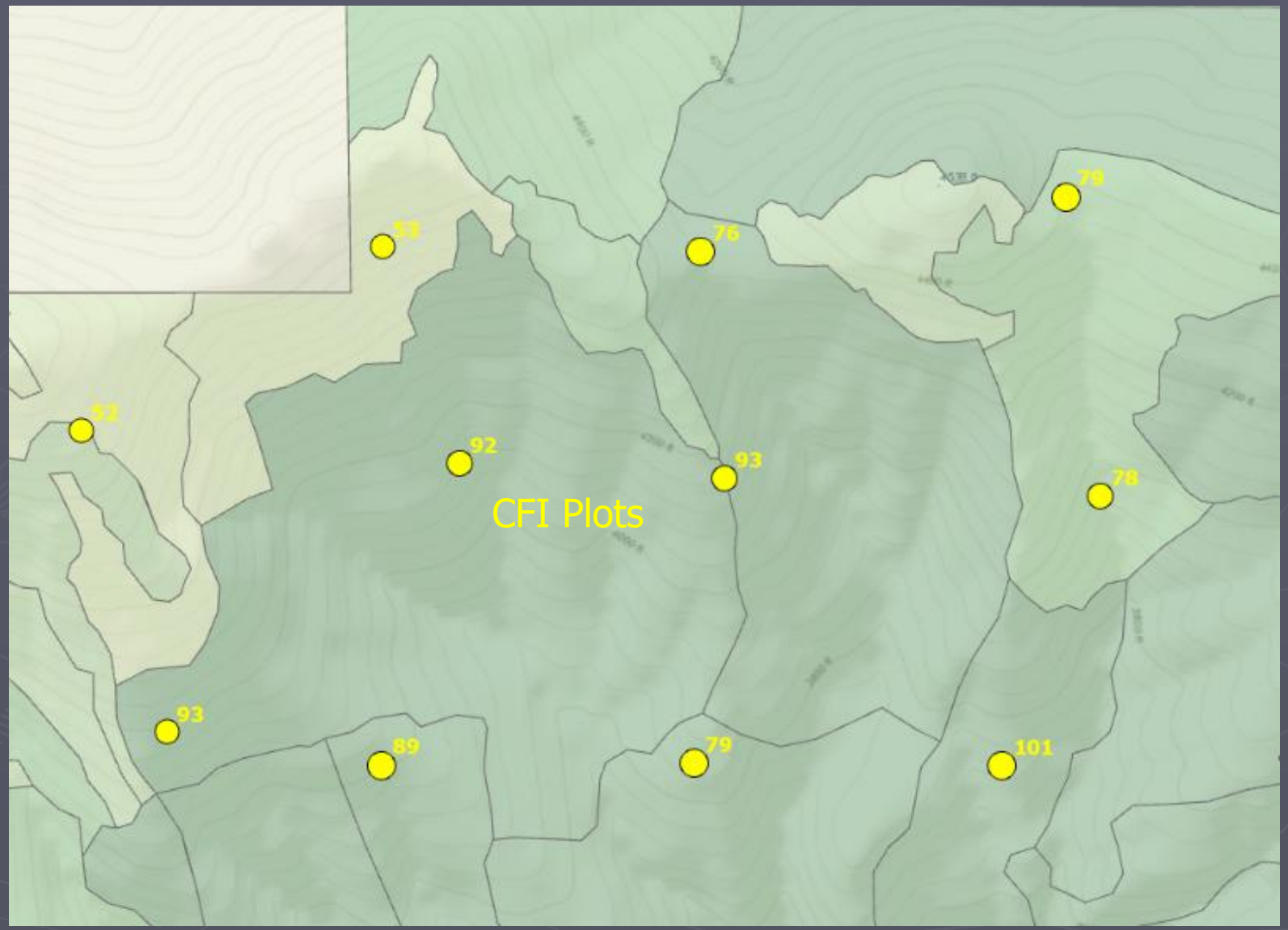
- The site index for CFI Plot 42 is the average site index of the <u>two</u> fastest growing trees: GF075 and WR070 which is 72 feet
- CFI Plot 42 site index is (75+70)/2 ≈ 72 feet
- If a CFI plot had four, five, or six trees, the site index of the plot was based on the average of the two fastest growing trees

Step 2: Assign a site index to each CFI plot (continued)

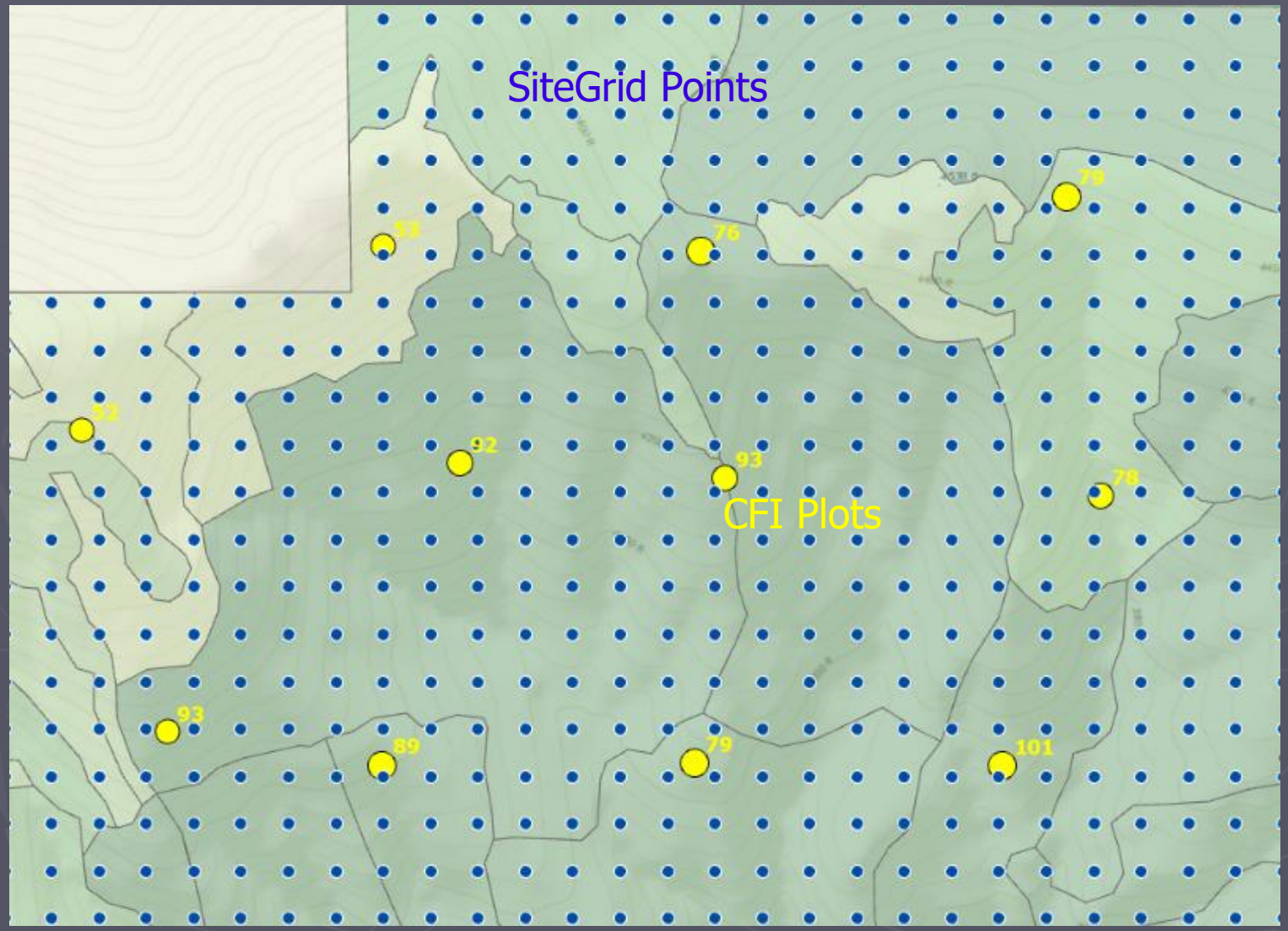
CFI Plot 29

- The site index for CFI Plot 29 is the site index of the fastest growing tree (GF058) which is 58 feet
- If a CFI plot only had one, two, or three trees the site index of the plot was solely based on the fastest growing tree

Conclusion of Step 2: Site index has been assigned to each CFI plot



Step 3: Develop a model to predict site index from environmental variables such as elevation, precipitation, solar radiation, and soil depth



SiteGrid Points

- Systematically placed within the Tribe's forest land (each SiteGrid point represents 1 acre)
- Populated with environmental variables such as elevation, precipitation, and soil depth
- Spatially join each CFI plot with the nearest SiteGrid point to prepare the data set needed for fitting models

Step 3: Develop a model to predict site index… (continued)

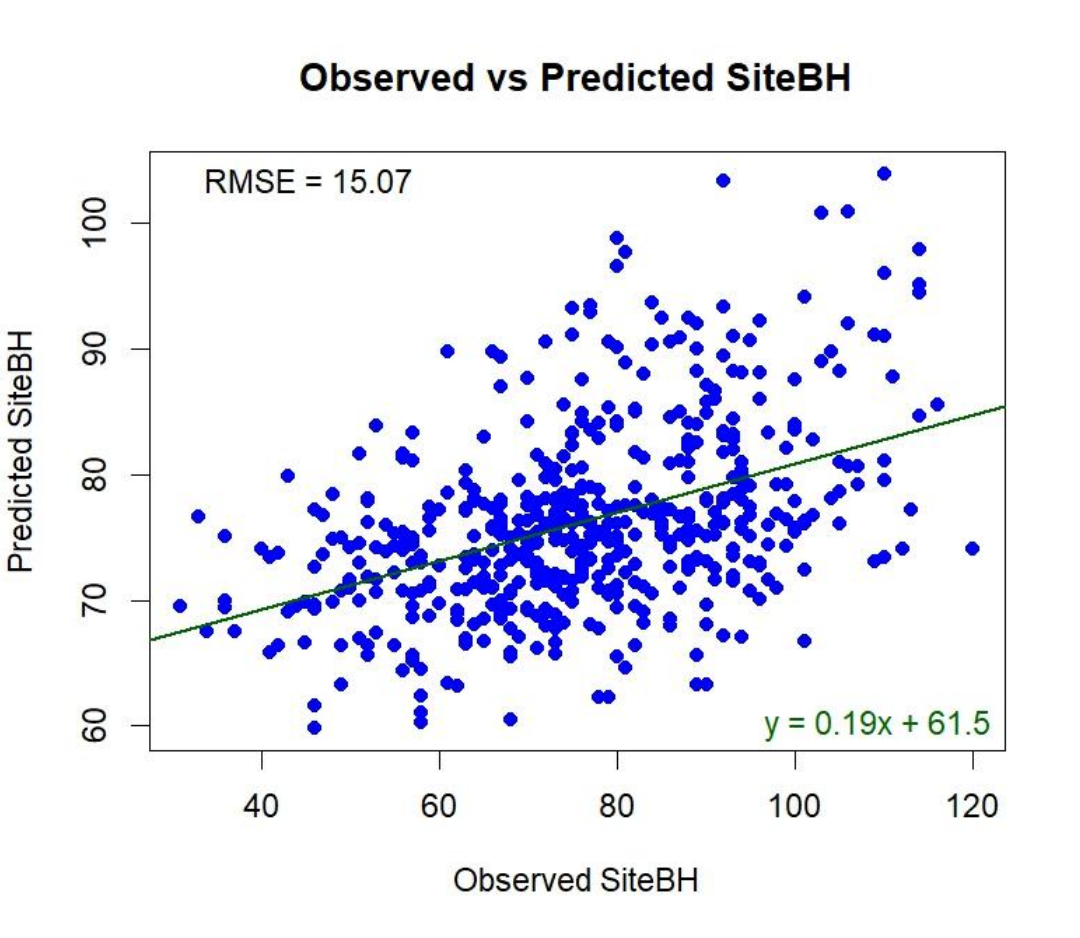
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	SiteCFI	Elev	Aspect	Slope	WetA	WetB	Sun2	Day2	Sun3	Day3	SoilC	SoilB	awcC	awcB	DayFF
2	63	2720	345	26	634	170	8.9	199	7.7	168	70.07	29.92	7.8	5.4	105
3	67	4119	231	44	1092	255	7.3	174	7.2	193	70.07	29.92	7.8	5.4	105
4	55	4292	236	44	1092	255	7.1	171	6.9	187	70.07	29.92	7.8	5.4	105
5	92	3569	294	32	1004	243	8.0	183	6.9	164	70.07	29.92	7.8	5.4	105
6	72	3949	281	38	1004	243	7.5	177	6.4	162	70.07	29.92	7.8	5.4	105
7	73	3148	307	26	762	194	8.4	191	7.5	170	70.07	29.92	7.8	5.4	105
8	54	4574	215	42	1338	324	6.7	165	7.0	191	70.07	29.92	0.2	0.2	110
9	73	4063	232	31	1127	273	7.4	174	7.4	189	70.07	29.92	6.7	5.0	105
10	77	4050	164	38	1152	279	7.4	174	7.8	205	70.07	29.92	0.2	0.2	110
11	61	3881	273	49	1120	272	7.6	177	6.3	165	70.07	29.92	6.7	5.0	105
12	89	3999	154	31	1223	297	7.4	175	7.8	199	70.07	29.92	0.2	0.2	110
13	106	4196	194	41	1267	307	7.2	171	0.1	33	70.07	29.92	0.2	0.2	110
14	84	4437	156	57	1171	283	6.9	167	7.0	205	70.07	29.92	0.2	0.2	110
15	93	4213	175	33	1210	294	7.2	171	7.7	200	70.07	29.92	0.2	0.2	110
16	88	4349	111	45	1200	290	7.0	169	6.5	175	70.07	29.92	0.2	0.2	110
17	76	3797	206	64	1120	272	7.7	179	7.6	219	70.07	29.92	0.2	0.2	110
18	58	4123	212	48	1171	283	7.3	173	7.4	204	70.07	29.92	0.2	0.2	110
19	73	4692	147	68	1200	290	6.6	163	6.3	199	70.07	29.92	0.2	0.2	110
20	92	4137	166	38	1223	297	7.3	173	7.7	204	70.07	29.92	0.2	0.2	110
21	67	4548	215	27	1267	307	6.8	165	7.1	184	70.07	29.92	0.2	0.2	110
22	53	4552	150	51	1194	289	6.8	165	6.9	197	70.07	29.92	0.2	0.2	110
23	44	4054	226	33	1044	255	7.4	174	0.1	1	70.07	29.92	0.2	0.2	110
24	94	4253	98	29	1255	304	7.1	171	1.8	102	70.07	29.92	0.2	0.2	110

SiteGrid_CFI points only

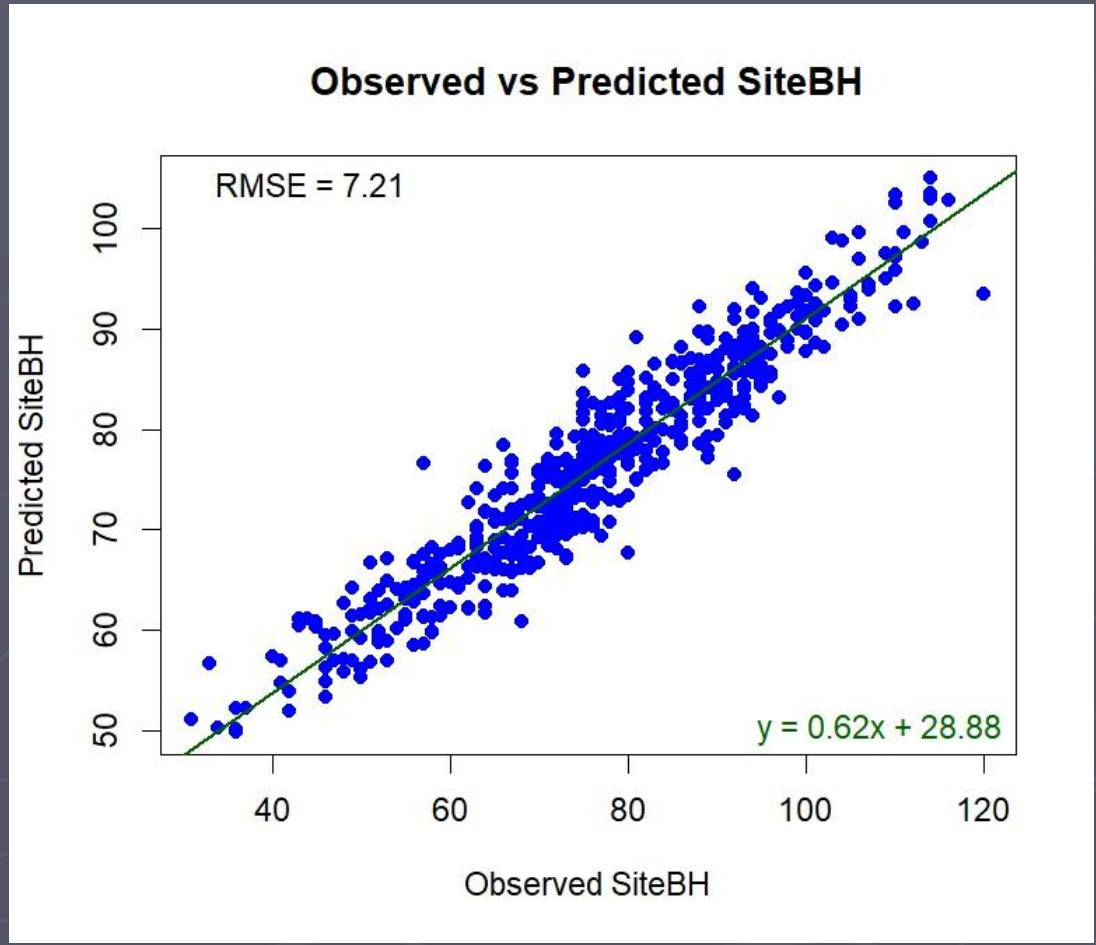
Step 3: Develop a model to predict site index… (continued)

- Two approaches were tested to develop site index prediction models

Stepwise linear regression $R^2 = 0.19$



Random forest regression $R^2 = 0.81$



Step 3: Develop a model to predict site index… (continued)

Great! Here's how to do **Recursive Feature Elimination (RFE)** in R with a `randomForest` model using the `caret` package.

✅ Step-by-Step: RFE with Random Forest in R

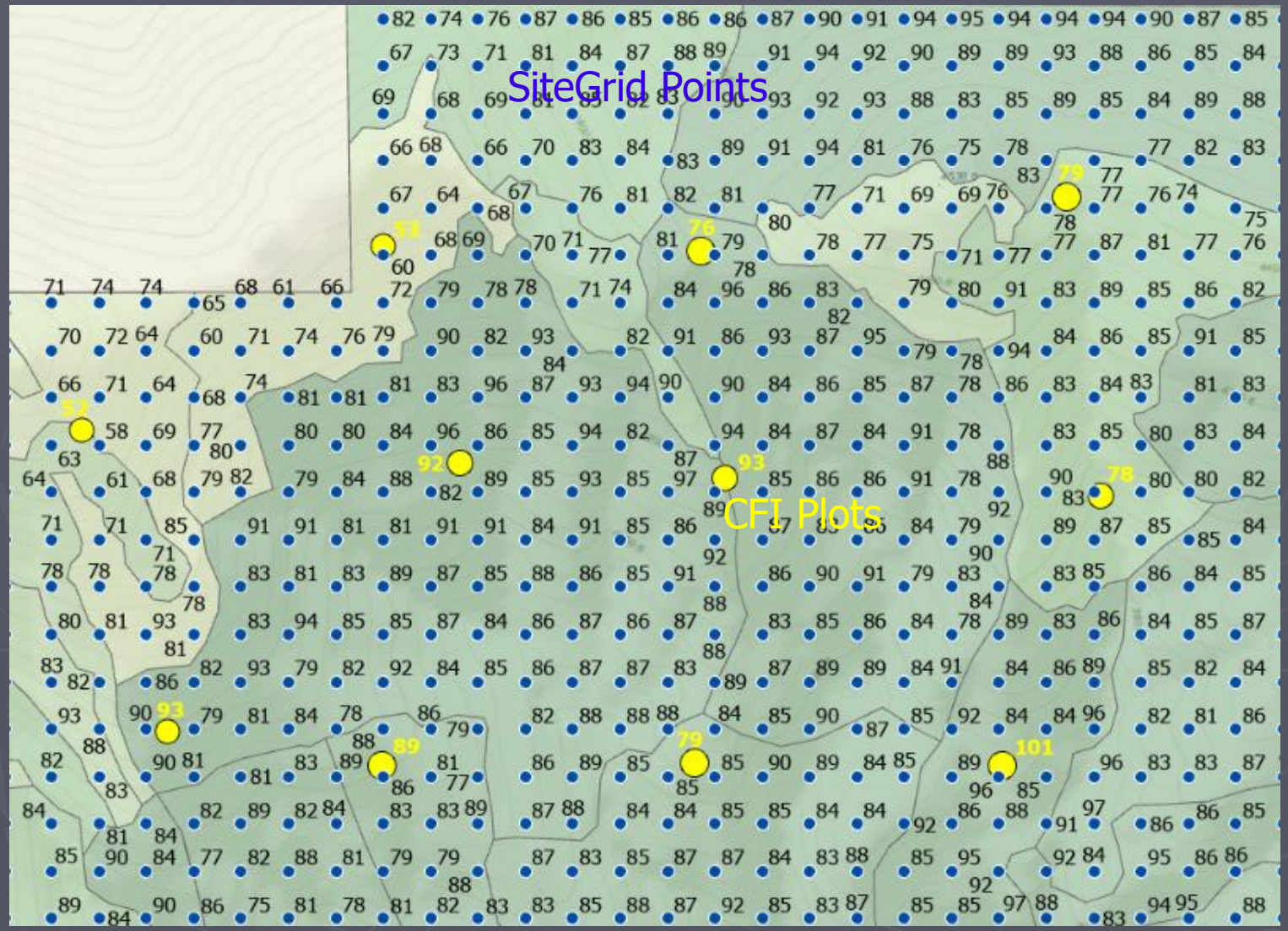
📦 Step 1: Install and Load Packages

r

Copy Edit

```r
install.packages("caret")
install.packages("randomForest")
library(caret)
library(randomForest)
```

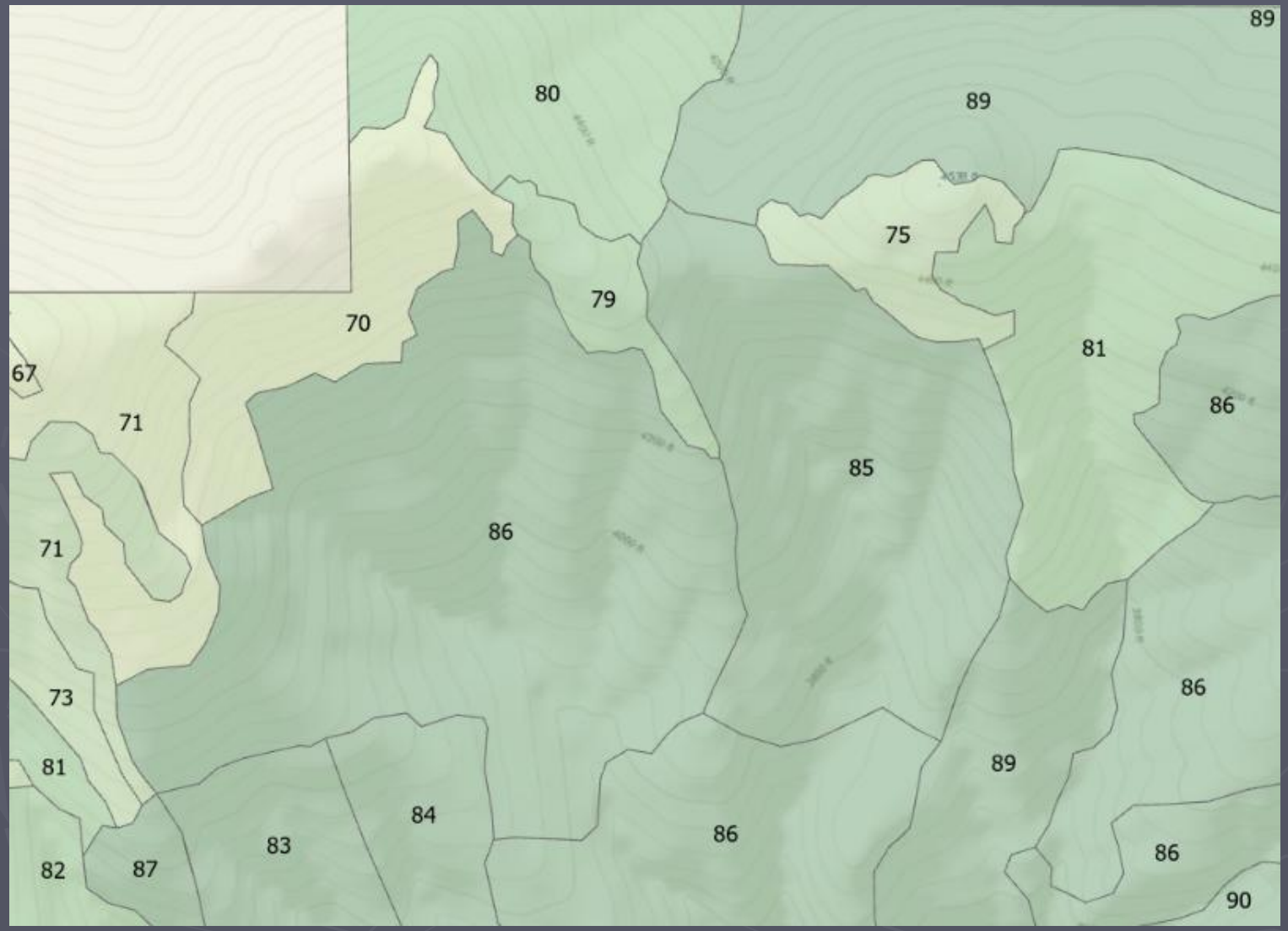
Step 4: Apply the randomForest model to every acre of the subject property



SiteGrid Points

- This map shows the predicted site index for each SiteGrid point

Step 5: Calculate the average site index for each forest stand and make a site productivity map for the property



Forest Stand Polygons

- Calculate the average site index for each stand in the inventory by averaging all the SiteGrid points that fall within the stan's boundaries

Step 6: Review the model, look for weaknesses, make incremental improvements if possible

In Process


Questions?
Forest
Biometrics
Research Institute