Supplementary:

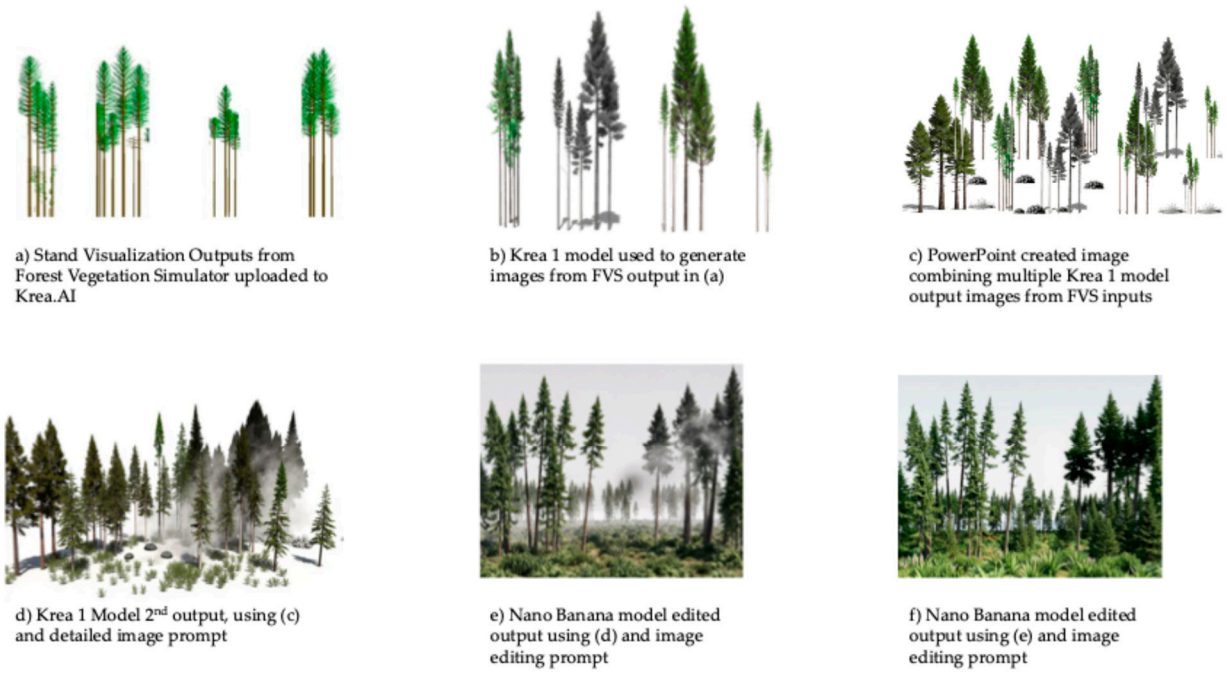


Figure S1. Description of creation of Figure 1 using Krea.AI. a) Stand data input from mature Dougals-fir stands (unpublished data) were input to the Forest Vegetation Simulator, stand visualization system outputs as input—this is one of several images used as input; b) Krea 1 image generation model used to create more natural looking Dougals-fir; c) PowerPoint image created using multiple outputs similar to "b)" and arranged into a clumped-tree landscape; d) Krea 1 model output using the image "c)" as a reference image and the Image Prompt: "Natural forest landscape with multiple distinct clumps of trees. Each clump contains 16–36 trees arranged in a dense central core and a looser outer ring. Inner-clump trees are always shorter and younger than the trees in the outer ring. There are no manmade objects in image. Prompt image objects are only trees or clumps of understory plants (ferns, 'salad[note autocorrected from salal]', huckleberry_ and bear grass). Hierarchy rules. Scene --> groups of ONLY 4 trees--> variability in groups of trees--> variability of trees in group. Rules applying to groups of 4 trees: each group is separated by 6 meters of a (not visualized grid). Rules for trees in group: groups vary in tree size crown height and ratio, trees within the group are arranged in a square of 3 m with each tree on a corner. Rules for space between groups: understory plants of salal, ferns, and huckleberries fill the scene. Salal is in clumps. ferns are in clumps, huckleberries are dispersed. grass is dispersed. There is some bare ground. If unsure, make space between clumps (groups of 4 trees) equally spaced. If unsure, make trees look similar to the prompt image. If unsure, do not add any non-plant objects. If unsure, all the trees are the species Douglas-fir. No trees are hardwood trees. If unsure, keep the aspect ratio. Fill the scene." e) Nano Banana Editor is used to create a more photograph appearing landscape using the following prompt "This is a wild forest scene with 3-dimensional space. There should be no buildings clouds are blurry spots. The smaller objects in the reference image are all p: shrubs or grass. use the original reference image for filling clumped space. the emphasis is groups of 15-20 trees and then space between them. some of the clumps should be in the distance with perspective. need to see 7-12 clips[autocorrected from clumps] total so scale appropriately. f) Nano Banana Editing of "e) Eliminate the grass flowers and dandelion heads. Double the number of ferns with vertical leaves. There should be clusters of ferns and clusters of the shrubs, instead of randomly mixed. The ferns go in lower spots (small valleys), and the shrubs on small ridges."

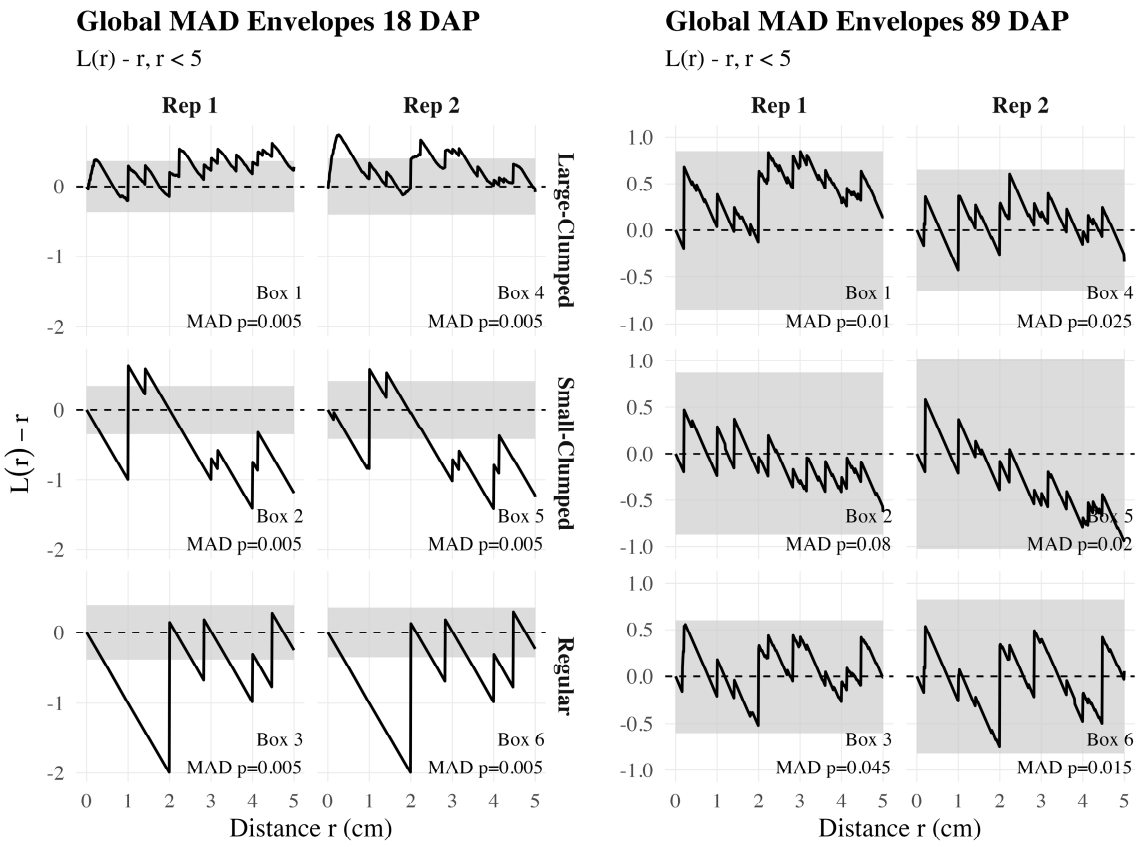


Figure S2. *L(r) – r* plots and mean absolute deviation (*MAD*) tests for global envelopes, with widths for each planting box calculated for *r*<5 demonstrating planting patterns 18 DAP (left), and at harvest 89 DAP (right). *MAD* test significant levels are for deviations of *L(r)* from 0-5 cm for complete spatial randomness (CSR) for observed values (solid line) and simulated values under CSR. All planting patterns are significantly different from CSR 18 DAP and multiple observed values are outside simulated significance bands. Top) Large-clumped planted patterns show significant, replicate-specific, clumping at multiple values of *r* 18 DAP; patterns are maintained 89 DAP. Middle) Small-clumped planted boxes show significant regular and clumped patterns at 1 cm (representing 1 cm 4-plant clumps and the regular spacing of individuals within the clumps (1 cm), and regular patterns at 3 and 4 cm—the space between clumps @ 18 DAP; the spatial pattern retains a regular patterning at scales > 2.5 cm 89 DAP. Regular-Square 2 cm spaced planted boxes show significant regular pattern at 2 cm@ 18 DAP, the 2 cm regular pattern is maintained @ 89 DAP.

Table S1. Comparison of tree spacing, arrangement (square vs. triangular and hexagonal), and group size on stand stocking in trees per hectare. Triangular arrangements are more efficient than square patterns and multiple arrangements and spacings are possible in producing similar stocking.

Arrangement	Space Between Trees (m) *(between groups)*	Group Spacing (m) or (# *of groups/ha)*	Square Trees/ha	Number of trees in group	Triangle[a] or Hexagon Trees/ha
Regular Pattern	2	N/A	2500	N/A	2887
	3	N/A	1111	N/A	1283
	4	N/A	625	N/A	721
	5	N/A	400	N/A	462
Regular Pattern 4-Tree Groups[b]	1	3	2500	4	N/A
	2	4	1111	4	N/A
	3	5	625	4	N/A
	4	6	400	4	N/A
Hexagonal Groups[c]	2(*2*)	*(167)*	N/A	6	1002
	2(*3*)	*(105)*	N/A	6	630
	3(*4*)	*(54)*	N/A	6	324
	4(*5*)	*(32)*	N/A	6	192
	2(*2*)	*(44)*	N/A	24	1056
	2(*3*)	*(34)*	N/A	24	816
	3(*5*)	*(14)*	N/A	24	336
	4(*5*)	*(9)*	N/A	24	216

[a]Triangle spacing calculation: $N = \frac{10{,}000}{S^2 * \frac{\sqrt{3}}{2}}$; where N is the #trees/ha and S is the space between trees. Hexagonal tree/ha is identical for continuous hexagons with a center tree. [b]Groups of 4 trees provide the possibility of adjusting space between trees and between clumps. The formula to find (N) trees/ha: Area occupied by a clump = $(a+b)^2$; where a is distance between trees in clump and b is distance between clumps, and N=10000/(clump area)*4. [c]Hexagonal groups of 6 individuals (1 hexagon), or 24 individuals in 7 hexagons. The number of groups for a single hexagon (6 points) was calculated by assuming a rectangular arrangement of hexagonal clumps. A rectangle of area occupied by each clump and a buffer space was calculated as: $A=[s + s + [\sqrt{3}a]\ x\ [s + s + [2a]]$; where s=the distance between hexagonal clumps, a=distance of hexagon side. For 7 hexagon clumps the area was calculated as $A= [s + s + (3\sqrt{3}a)]]\ x\ [s + s + \sqrt{3}a] + (2 * (2a))]$.

Table S2. Mean, standard deviation and sample size {n} for plant measurements by treatment and replicate at maturity. Crown volume was calculated from crown height, crown height to first leaf, and crown width. Crown ratio was calculated as (crown height – height to first leaf)/crown height). Crown heights, basal diameters, stem sweep from vertical and longest straight stem were measured for all plants at maturation. The other measurements were taken for plants in a center core to assure no edge effects. Note, edge effects were minimized for light differences by weekly upward expansion of cardboard barriers.

Variable	Treatment	Replicate	Mean	Standard deviation	n
Height of first leaf	Large-clumped	Large-clumped-1	19.06	6.47	25
		Large-clumped-2	16.79	6.62	32
	Small-clumped	Small-clumped-1	20.94	8.64	23
		Small-clumped-2	24.20	6.51	21
	Regular-square	Regular-square-1	20.73	8.11	37
		Regular-square-2	17.11	8.43	31
Diameter at base	Large-clumped	Large-clumped-1	2.67	0.68	115
		Large-clumped-2	2.81	0.89	124
	Small-clumped	Small-clumped-1	2.62	0.95	99
		Small-clumped-2	3.04	0.86	78
	Regular-square	Regular-square-1	2.39	0.78	128
		Regular-square-2	2.89	0.93	104
Diameter of largest branch	Large-clumped	Large-clumped-1	1.68	0.56	12
		Large-clumped-2	1.85	0.68	21
	Small-clumped	Small-clumped-1	2.04	0.45	14
		Small-clumped-2	1.68	0.48	12
	Regular-square	Regular-square-1	1.50	0.53	22
		Regular-square-2	2.13	0.35	13
Crown ratio	Large-clumped	Large-clumped-1	0.45	0.13	25
		Large-clumped-2	0.53	0.15	32
	Small-clumped	Small-clumped-1	0.33	0.18	20
		Small-clumped-2	0.36	0.15	21
	Regular-square	Regular-square-1	0.25	0.11	36
		Regular-square-2	0.48	0.19	31
Crown width	Large-clumped	Large-clumped-1	11.62	4.96	25
		Large-clumped-2	14.39	4.28	32
	Small-clumped	Small-clumped-1	18.04	5.25	17
		Small-clumped-2	14.66	3.34	17
	Regular-square	Regular-square-1	10.53	3.93	35
		Regular-square-2	8.96	3.94	31
Crown Volume	Large-clumped	Large-clumped-1	789.93	843.37	25
		Large-clumped-2	1,359.85	1,167.10	32

Variable	Treatment	Replicate	Mean	Standard deviation	n
	Small-clumped	Small-clumped-1	1,720.02	1,686.25	16
		Small-clumped-2	1,335.45	1,069.66	17
	Regular-square	Regular-square-1	303.72	326.53	35
		Regular-square-2	584.93	680.58	31
Height: diameter ratio	Large-clumped	Large-clumped-1	124.23	39.91	114
		Large-clumped-2	124.85	57.88	121
	Small-clumped	Small-clumped-1	127.42	118.99	96
		Small-clumped-2	131.44	36.76	78
	Regular-square	Regular-square-1	110.89	36.52	124
		Regular-square-2	115.80	40.96	104
Stem straightness	Large-clumped	Large-clumped-1	4.54	3.39	116
		Large-clumped-2	3.36	2.33	123
	Small-clumped	Small-clumped-1	3.25	1.52	102
		Small-clumped-2	6.50	3.54	79
	Regular-square	Regular-square-1	3.12	2.23	123
		Regular-square-2	3.69	2.64	104
Crown height	Large-clumped	Large-clumped-1	32.95	13.90	117
		Large-clumped-2	33.73	14.61	123
	Small-clumped	Small-clumped-1	30.38	13.25	100
		Small-clumped-2	40.69	17.04	79
	Regular-square	Regular-square-1	26.67	11.25	125
		Regular-square-2	34.43	17.74	104
Diameter at Base of crown	Large-clumped	Large-clumped-1	1.52	0.41	25
		Large-clumped-2	4.25	5.73	32
	Small-clumped	Small-clumped-1	1.50	0.38	22
		Small-clumped-2	1.85	0.48	20
	Regular-square	Regular-square-1	1.75	0.61	38
		Regular-square-2	1.95	0.44	31
Longest straight stem	Large-clumped	Large-clumped-1	11.96	7.85	118
		Large-clumped-2	10.93	6.26	124
	Small-clumped	Small-clumped-1	14.57	9.90	102
		Small-clumped-2	11.82	5.94	79
	Regular-square	Regular-square-1	6.14	3.84	122
		Regular-square-2	15.50	10.08	104
Number of leaves	Large-clumped	Large-clumped-1	11.48	6.22	25
		Large-clumped-2	18.42	11.26	33
	Small-clumped	Small-clumped-1	13.65	9.58	23

Variable	Treatment	Replicate	Mean	Standard deviation	n
		Small-clumped-2	13.76	6.02	21
	Regular-square	Regular-square-1	11.89	7.20	37
		Regular-square-2	14.19	7.35	31
Number of flowers	Large-clumped	Large-clumped-1	1.03	1.07	118
		Large-clumped-2	2.06	3.73	126
	Small-clumped	Small-clumped-1	1.13	1.22	104
		Small-clumped-2	1.21	1.16	78
	Regular-square	Regular-square-1	1.09	1.18	127
		Regular-square-2	1.24	1.48	106

Table S3. Kruskal-Wallis for differences in treatment at maturity, with 2 replicates per box.

Variable	statistic	df	p.value	n_boxes_total
Crown height	0.2857143	2	0.8668779	6
Crown ratio	2.0000000	2	0.3678794	6
Crown volume	3.7142857	2	0.1561180	6
Crown width	4.5714286	2	0.1017014	6
Diameter at base	0.2857143	2	0.8668779	6
Diameter of largest branch	0.2857143	2	0.8668779	6
Diameter of crown	0.8571429	2	0.6514391	6
Height: diameter ratio	4.5714286	2	0.1017014	6
Height to first leaf	3.7142857	2	0.1561180	6
Longest stem	0.2857143	2	0.8668779	6
Stem straightness	0.8571429	2	0.6514391	6

Table S4. ANOVA for differences in treatment at maturity, with 2 replicates per box for 3 treatments: Large-clumped , Small-clumped, Regular-square.

Variable	Analysis scale	term	df	sumsq	meansq	statistic	p.value
Height of first leaf	Raw (box mean)	treatment	2	23.9667	11.9833	2.4858	0.23085
Height of first leaf	Raw (box mean)	Residuals	3	14.462	4.8205		
Diameter base	Raw (box mean)	treatment	2	0.035	0.0178	0.2417	0.79919
Diameter base	Raw (box mean)	Residuals	3	0.2212	0.0737		
Diameter largest branch	Raw (box mean)	treatment	2	0.0087	0.0043	0.0466	0.95510
Diameter largest branch	Raw (box mean)	Residuals	3	0.2798	0.0932		
Crown ratio	Raw (box mean)	treatment	2	0.0282	0.0141	1.1213	0.43286
Crown ratio	Raw (box mean)	Residuals	3	0.038	0.0126		
Crown width	Log (box_mean)	treatment	2	0.2667	0.1333	6.9796	0.07439
Crown width	Log (box_mean)	Residuals	3	0.0573	0.0191		
Crown volume	Log (box_mean)	treatment	2	1.728	0.8639	6.5727	0.08009
Crown volume	Log (box_mean)	Residuals	3	0.394	0.1314		
Height: diameter ratio	Log (box_mean)	treatment	2	0.019	0.0093	19.613	0.01893
Height: diameter ratio	Log (box_mean)	Residuals	3	0.0014	0.0005		
Stem straightness	Boxcox (lambda=-2)	treatment	2	0.0002	0.0001	0.3482	0.73111
Stem straightness	Boxcox (lambda=-2)	Residuals	3	0.001	0.0003		
Crown height	Boxcox (lambda=-0.2)	treatment	2	0.005	0.0028	0.4505	0.67439
Crown height	Boxcox (lambda=-0.2)	Residuals	3	0.018	0.0062		
Diameter crown base	Boxcox (lambda=-2)	treatment	2	0.003	0.0019	0.2762	0.77602
Diameter crown base	Boxcox (lambda=-2)	Residuals	3	0.021	0.0070		
Longest straight stem	Boxcox (lambda=2)	treatment	2	572.3	286.13	0.1465	0.86949
Longest straight stem	Boxcox (lambda=2)	Residuals	3	5,856.3	1,952.11		

Table S5. Tukey post-hoc comparison among treatments for crown variables at maturity.

Variable	Comparison	diff	lwr	upr	p adj
Crown ratio	Regular-square-Large-clumped	0.134752382	-0.33436120	0.60386596	0.52950623
Crown ratio	Regular-square-Small-clumped	-0.019681714	-0.48879529	0.44943187	0.98329162
Crown ratio	Small-clumped-Large-clumped	0.154434096	-0.31467948	0.62354768	0.45398691
Crown width	Regular-square-Large-clumped	-0.286077527	-0.86365516	0.29150011	0.24332129
Crown width	Regular-square-Small-clumped	-0.515366796	-1.09294443	0.06221084	0.06684411
Crown width	Small-clumped-Large-clumped	0.229289269	-0.34828837	0.80686690	0.35175951
Crown volume	Regular-square-Large-clumped	-0.899743822	-2.41473410	0.61524646	0.17071942
Crown volume	Regular-square-Small-clumped	-1.279760426	-2.79475071	0.23522986	0.07656799
Crown volume	Small-clumped-Large-clumped	0.380016604	-1.13497368	1.89500689	0.60191214
Height: diameter ratio	Regular-square-Large-clumped	-0.094433708	-0.18565037	-0.00321705	0.04568780
Height: diameter ratio	Regular-square-Small-clumped	-0.132834658	-0.22405132	-0.04161800	0.01811953
Height: diameter ratio	Small-clumped-Large-clumped	0.038400950	-0.05281571	0.12961761	0.32125038