SADC Regional Programme for Rhino Conservation
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VISUAL ASSESSMENT OF BLACK RHINO BROWSE AVAILABILITY V2.1

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A: INTRODUCTION

This manual provides a definition and step-by step description of "browse availability scoring" - a standardised, visual method of assessing browse availability for black rhino. It also describes how to plan a comprehensive browse availability survey for an entire property or reserve.

Before undertaking a real survey of black rhino browse availability, beginners to this approach need to first do the following:

- **read and properly understand the material presented in sections B to D**
- **practice and become confident with each aspect of the assessment technique, by undertaking the practice sessions given in appendix 3.**

This document is a companion to the *User Guide to the RMG Black Rhino Carrying Capacity Model (Adcock 2001)*, updating the approach to browse availability assessment given there, as well as updating the first versions of this document (Visual assessment of black rhino browse availability, Adcock, October 2003, and Version 2.0 of October 2004).

Justification for the technique described here is provided in the last section "E" of this document. Readers are also referred to an inter-observer variability test of the technique, *"Report on the field testing of inter-observer variability in the application of the standardised browse availability assessment method used in black rhino carrying capacity evaluation"* (Adcock, July 2004).

B: CHARACTERISTICS OF BLACK RHINO BROWSING: IMPORTANT POINTS

Around 98% of black rhino food comes from the 0-2m height range, and around 85% comes from the <1.5m height range. Rhino prefer feeding between 0.50m and 1.20m in most savanna areas.

Generally, browse material above the 2m level is unavailable to black rhino. They can use browse from above 2m, when they can bend or push down tall plant specimens, bringing them into the <2m browse layer. This behaviour tends to be confined to certain preferred plant species or spindly growth forms. For browse availability assessment purposes, browse material over 2m off the ground is ignored, as in real terms it still only contributes a tiny proportion of rhino diet.

Black rhino consume leaves and significant amounts of twigs/branches, up to a maximum stem diameter of around 3cm, depending on the hardness of the wood. Generally, black rhino routinely eat twigs of up to 1.5 cm diameter.

Patterns of woody plant eating tend to be species and growth form dependent.

- Longer, thicker shoots or small branches are removed from spindly plant growth forms, where most of the branches are available to rhino (left)

- In contrast, on a heavily hedged plant form, multiple short, thin shoots tend to be trimmed off the relatively shallow outer layer (shell) of the plant, and most of the inner branchlets are unavailable to the rhino (right).

Dead plant parts (e.g. dead branches and twigs) *are not eaten by black* rhino and must be excluded during browse availability assessment.

Burnt branches and twigs however are relished by black rhino. Rhino eat the twigs which are not too badly burnt (i.e. not totally charcoalised right through), and which have some sap and cell content still present in them (i.e. still alive or dying twigs). They even prefer burnt twigs to unburnt twigs!

C: WHAT DOES BLACK RHINO BROWSE AVAILABILITY (BA) MEASURE?

Browse availability (BA) is an "Index" that is *correlated* with the actual biomass of potential black rhino browse at a given site. The correlation works through the fact that the canopy dimensions of a plant are correlated with the amount (weight) of browsable material on a plant (see section E for a theoretical background to the technique).

- ***The 0-2m space layer over a given plot area defines a potential "browse space" or "pie" for black rhino.***

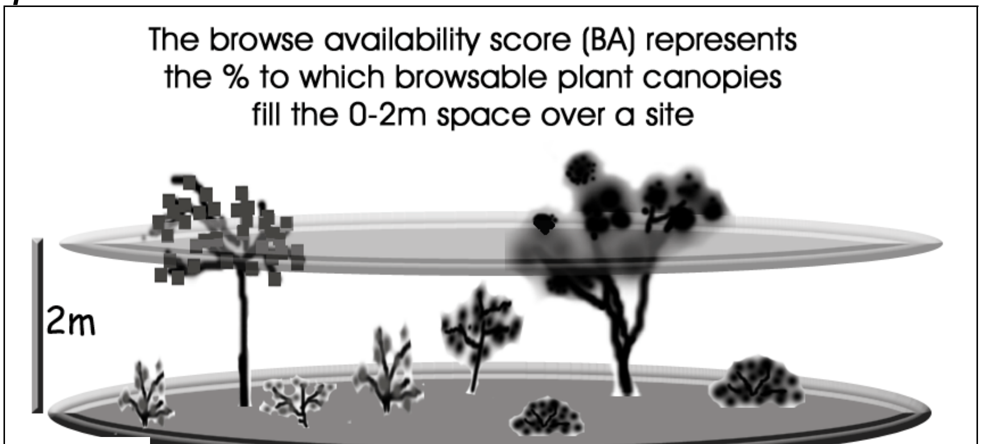


Fig. 1

- ***The degree to which this pie is filled by browsable plant canopy material provides an index of browse availability for black rhino.*** (For example, a site filled solidly from 0m to 2m with browse (browsable plant canopies), would contain 100% "fill" of the rhino pie, or 100% browse availability.)

- In most situations, the 0-2m browse pie is not filled entirely with browse. ***The summed volumes of the individual plant canopies in the area, expressed as the % fill of the "pie", provide a relative estimate of available browse.***

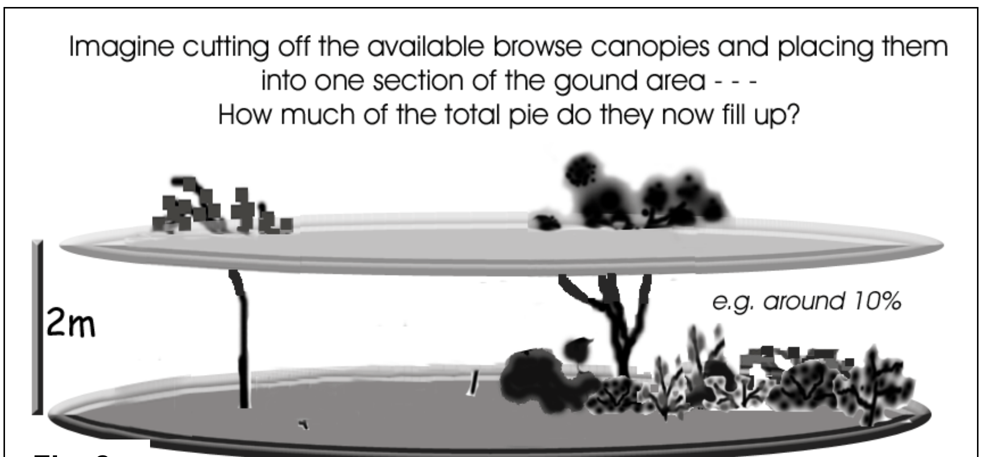


Fig. 2

The BA score (% fill) represents the amount of potential food available to black rhino. BA is assessed separately from the browse palatability or suitability, because it is a variable with its own strong influence on black rhino carrying capacity.

D: HOW TO ESTIMATE BROWSE AVAILABILITY (% FILL)

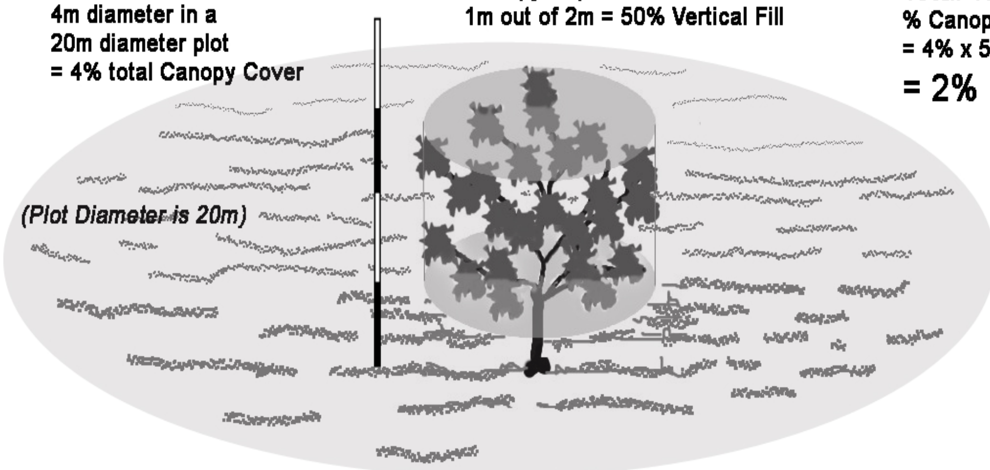
- Browse availability is assessed by eye in the 0 to 2 metres layer over a given ground area or plot. ***Use a light-weight 2m pole, calibrated in 10cm units, to assist you with canopy depth estimation. Also take a small hand-held calculator to save taxing the brain.***

- In each plot, the task is to estimate the % of pie space that is filled with browsable material within in the 0 to 2m height range. (A datasheet is provided in appendix 2)

- This is done by assessing two plot characteristics:

1. ***total % canopy cover,*** and
2. ***% vertical fill*** , and then
3. ***multiplying these two together (as proportions) to get a total % fill = Total %BA***.

This example shows how, …..and why this works:



<u>This is how one would have done it by measuring actual plant canopy diameters and depth *(i.e. the long way)*:</u>

Lower canopy level= 50cm
Upper canopy level = 1.5m
Canopy depth = 1m

Average canopy diameter = 4m (=2m radius)

<u>Volume of plant canopy</u> = Canopy area x canopy depth

Canopy area = PI x radius squared
= 3.2415926 x (2 squared) = 12.57m2
Canopy area X canopy depth = 12.57m2 x 1m
= 12.57m3

<u>Volume of Plot = Plot Area x Plot Depth (2m)</u>

Plot area = PI x radius squared
= 3.1415926 x (10 squared) = 314.159m2
Plot Volume = 314.159m2 x 2m
= 628.32m3

TOTAL % FILL=
Canopy Volume as a % of Plot Volume =
12.57m3 / 628.32m3 = 0.02 = **2%**

- ***Different components of vegetation*** at a site can be assessed separately where needed. These can be viewed as different vegetation "layers"

For example,

Herbs (excluding grasses) are often best assessed separately from woody browse, but in exactly the same way. = herb layer

Dwarf shrubs (e.g. **karroid** bushes) = a low layer

Small woody plants (seedling or sapling etc.) = a low layer

Overstory canopies of larger trees = a high layer

etc.

The BA score of each layer is added together to arrive at an overall BA score for the site.

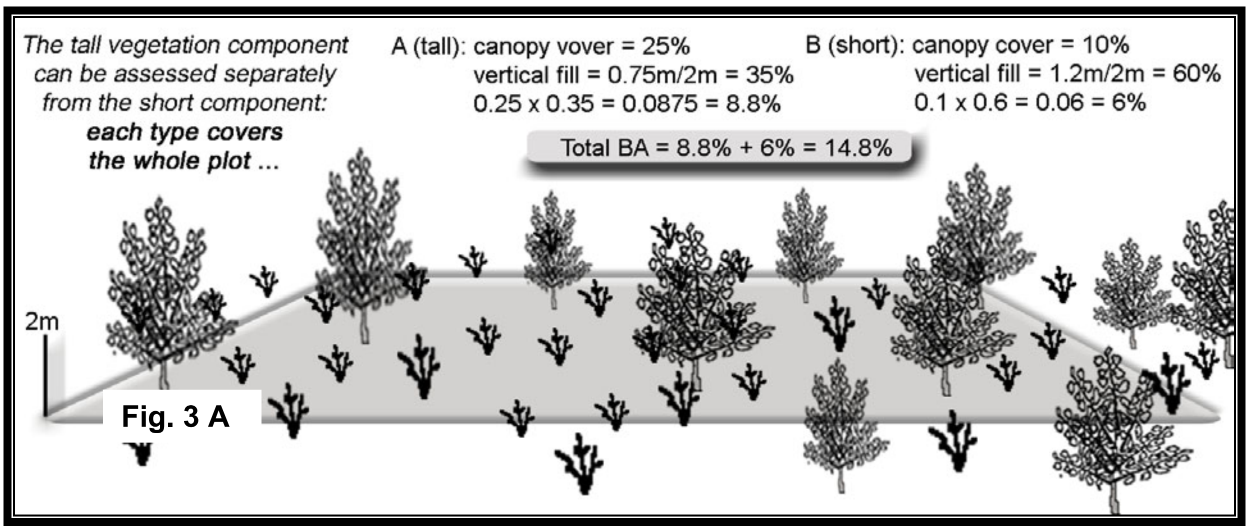


Fig. 3 A

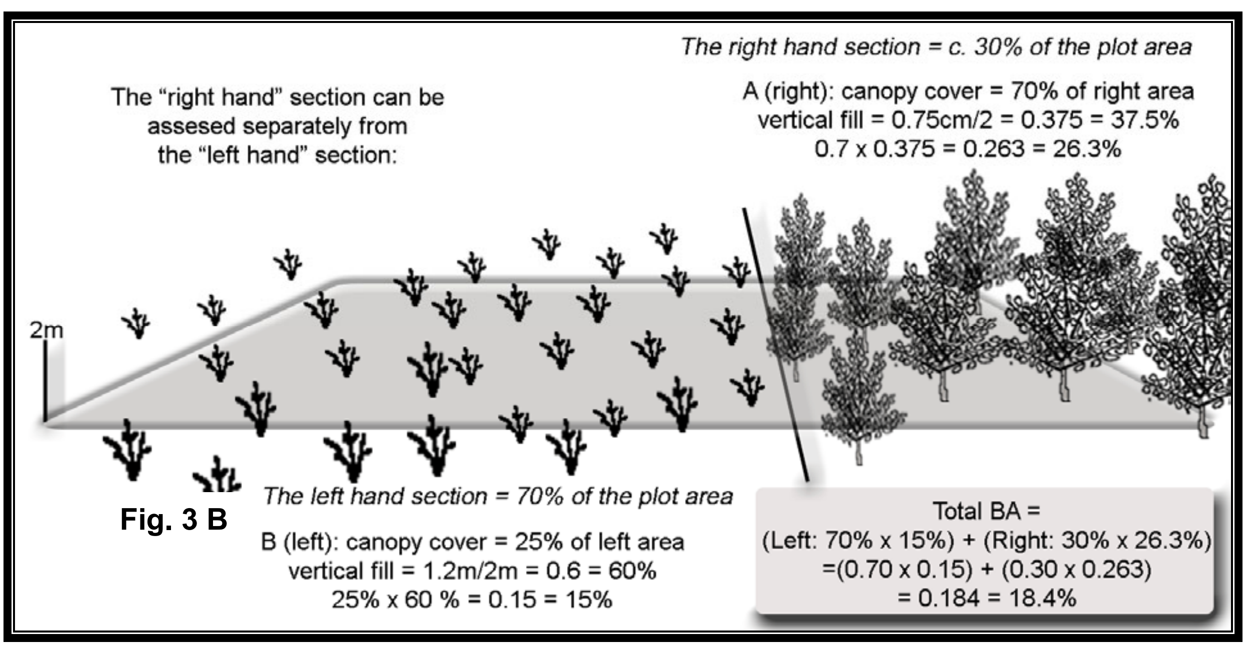


Fig. 3 B

1. Assessing total % Canopy Cover

The ground-projected browse canopy cover is rated on a scale of 0 to 100% of the plot area.

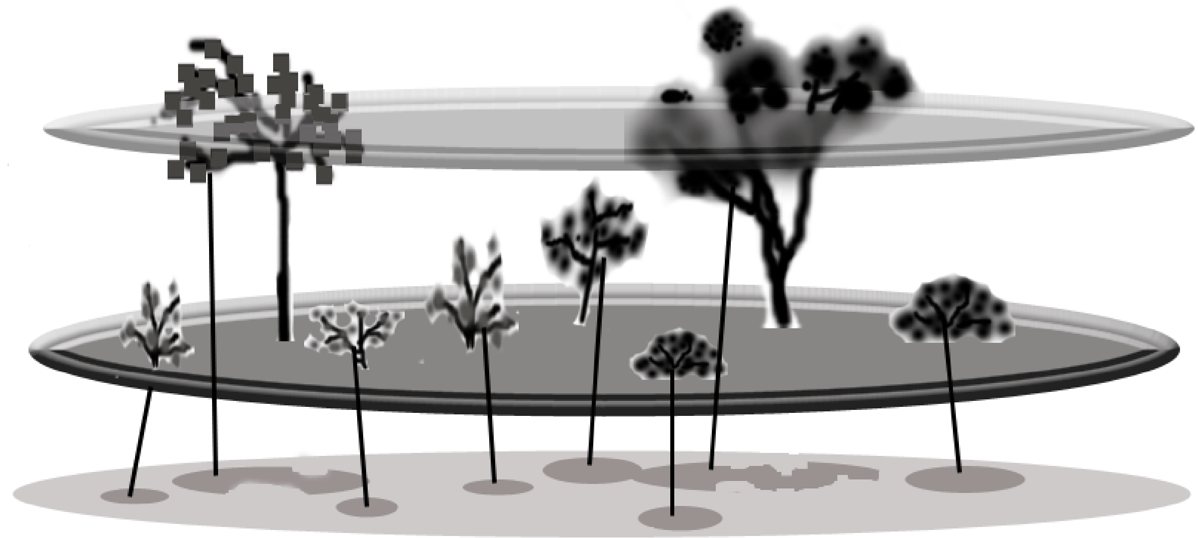


Fig. 4

Note: in general, canopies of plant growing under other plants need to be visually "moved" into unoccupied ground area to estimate the correct total plot canopy "cover".

Total % canopy cover estimation can be done through three approaches:

A) By visually re-arranging the available browse canopies into one segment of the plot, and judging how much of the plot ground area would be covered up.

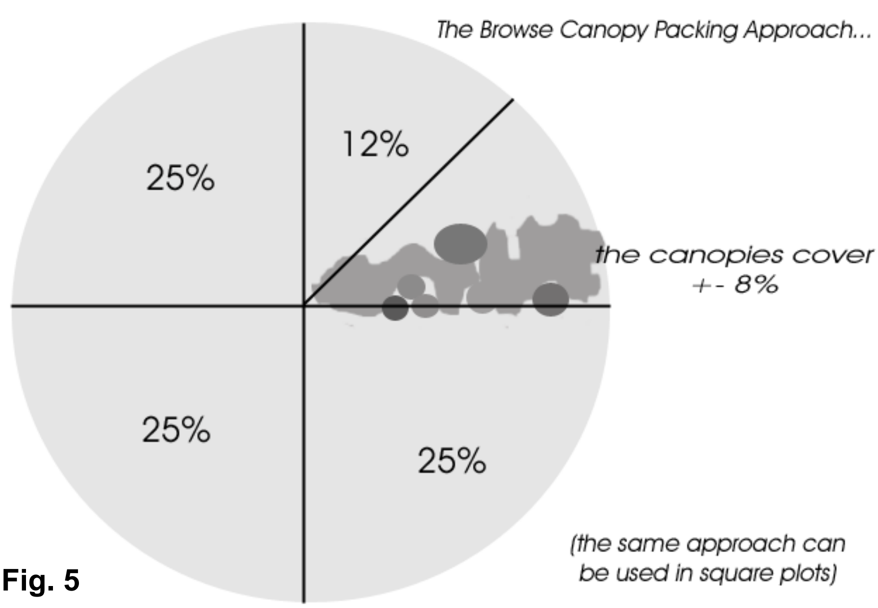


Fig. 5

B) By trying to match the observed pattern and level of cover versus space observed in your plot with calibrated canopy cover % images: Print out and use the visual aids provided in Appendix 1, which show a range of cover patterns for 0.5% to 90% canopy covers.

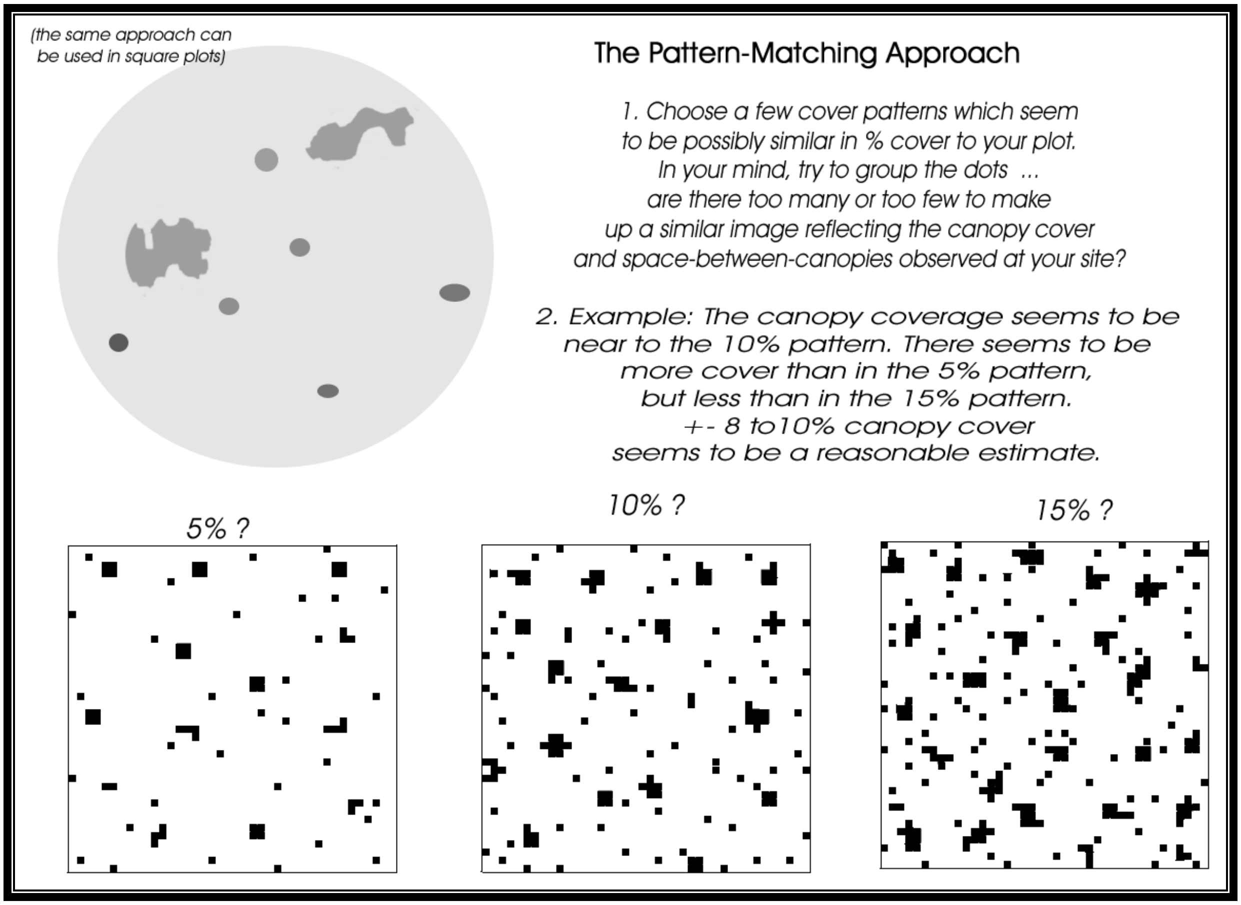


Fig 6

C) By knowing that canopies of a certain dimension represent a certain percentage of a given plot size, the total canopy cover can be estimated. E.g. small canopies can be visually "bundled" together to form units of 1% cover which can be counted up.

- A canopy averaging **2 x 2m** square equals **1%** of a **20 x 20m** square plot.
- A circular canopy averaging **2m diameter** equals **1%** of a circular plot of **20m diameter**.
- A canopy of 3**x3m** square equals **9%** of a **10 x 10m** square plot.
- A circular canopy of 3**m diameter** equals **9%** of a **10m diameter** plot.

etc etc…

Summary Tables, showing the % cover represented by different sized canopies in different sized plots, are provided for use in the field in appendix 1.

Things to remember when estimating canopy cover:

- When projecting a canopy's cover shape onto the ground, ignore odd twigs and bits that may stick out of the main canopy shape – i.e. don't try to project a circle/ellipse/oblong that encloses every little bit of the canopy, as this area be will be an overly large representation of the lateral canopy dimensions.

- When projecting canopy cover onto the ground area, canopies which occur largely underneath other ones need to be "shifted sideways" into "open space", to account for canopy overlapping (Do not worry to adjust for canopies which overlap only slightly at their tips).

- If many small plants occur under large ones (e.g. herbs under trees or bushes), assess the average canopy cover and average canopy depth of these plants separately as a separate layer.

- If the canopies of the "understory" meet and intermix with the canopies of the "overstory" or upper browse layer, it can be difficult to work out where on layer begins and the other ends. In this case, treat the entire bundle as one canopy and do not separate the canopy covers of the upper and lower layer. The entire bundle's canopy depth also needs to be judged as the lower + upper layer canopy depths added together also.

- Canopies of tall trees often have a "doughnut" shaped projected available canopy, i.e. the central part of the canopy in many trees often contains only thick branches and stems. Only the outer ring of smaller branches and twigs+leaves comprises available browse. Do not include the centre of such tree "canopies" in your projected canopy cover estimation.

- Very large, tall bushes also usually have a central region which has no available browse. You should estimate what percentage of such bush canopy area is "empty", and this area must also be deducted from the bush canopy cover estimate.

- Sometimes a site has large shrubs with very sparse canopies within the 0-2m level, i.e. the browsable canopy consists of small, widely spaced bunches of leaves/twigs of 10-30cm diameter, scattered around a bush canopy which may be 5m + in diameter. Here, you need to do the following (treating such bushes as a separate layer:

    - Estimate the % canopy cover of the entire reachable bush canopy
      [e.g. 20% of the plot, or 0.2]
    - Then estimate the % of this canopy cover that actually has bits of browsable material
      [e.g. 30% or 0.3]
    - Multiply these together to get a more realistic estimate of browsable canopy cover for this bush:
      [i.e. 0.2 x 0.3 = 0.06 = 6%]

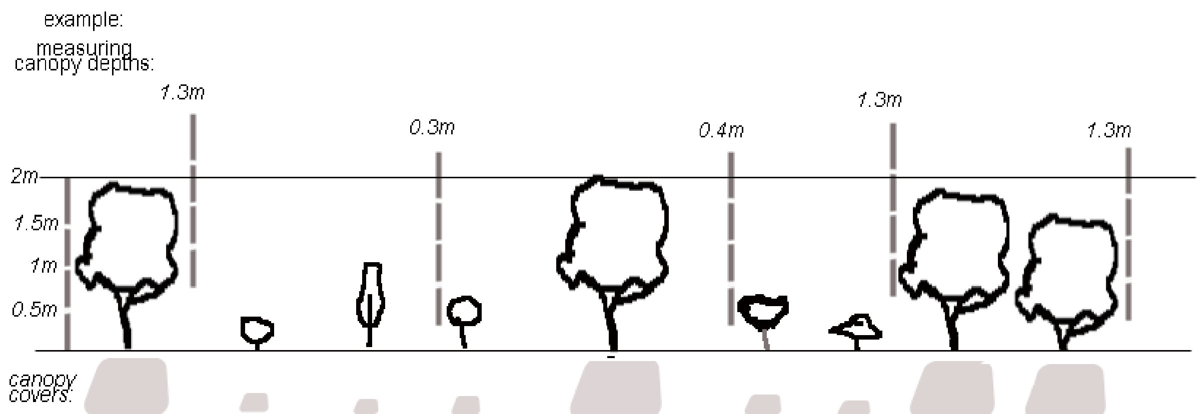
2. Assessing Vertical Fill

The *weighted* average vertical “depth” or “thickness” of the browsable plant canopies is estimated in metres, and converted to a % of 2 metres (i.e. halved).

vertical fill = wt’d avg. canopy depth(m) / 2m

e.g. wt’d avg. depth = 0.5m   0.5/2 = 0.25 or 25%.

Because wide canopies contributes more to total canopy cover, the average depth is weighted more towards wider plant canopies residing in the 0-2m layer. One naturally tends to correctly weight the browse canopies when judging (weighted) average canopy depth by eye – see the figure below for an explanation.



Large canopy covers make up +-80% of total canopy cover, and small canopies make up +-20% of the total canopy cover

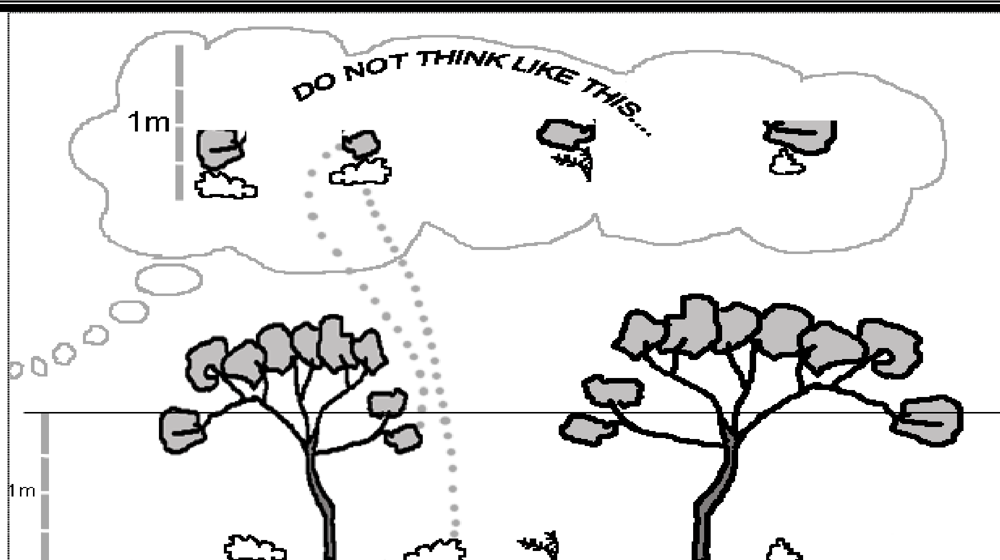
thus canopy depths from large shrubs must contribute about 80% to the weighted average canopy depth, and small shrubs must contribute 20% to the average canopy depth.

average canopy depth of large shrubs (making 80% of the canopy cover) = +- 1.3m   0.8 * 1.3 = 1.04m
+ average canopy depth of small shrubs (making 20% of the canopy cover) = +- 0.4m   0.2 * 0.4 = 0.08m

overall average canopy depth = 1.12m

Fig. 7

Proportion Vertical Fill = 1.12m / 2m = 0.56   (or 56%fill)



In this plot, the individual sections of canopy on trees and on bushes are each 0.4-0.5m "deep", giving an average % vertical fill of 0.45/2 = c. 22%.

Do not be tempted to pile the sections one on top of the other to work out the% vertical fill!

Fig. 8

- **Table for estimating vertical fill:**

When the available woody plant canopy structure is fairly varied at a site, this table can be shaded in while in the field. *Decide on 2 or 3 "classes" of canopy depth, and estimate their % contribution to total canopy cover and their average depth separately*. The answer can be calculated out in the field, or the table shading can be entered later onto a computer spreadsheet, to calculate the proportion of vertical fill.

In the field, just shade in the average canopy depth as a % of total canopy cover of each class of available woody plant canopy (all columns thus get some depth value to make 100% of whatever canopy cover there is). To do the calculation in the field, just add up how many squares have been shaded in, and divide this number by 2 to get the final % fill. (Divide this by 100 to get the proportion filled).

CANOPY DEPTH

CANOPY DEPTH												
2.0												
1.9												
1.8												
1.7												
1.6												
1.5												
1.4												
1.3											2	
1.2											2	
1.1											2	
1.0											2	8
0.9											7	
0.8											7	
0.7											7	
0.6											7	
0.5											7	42
0.4											7	
0.3											10	
0.2											10	30
0.1											10	
0.0	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	80	filled
	% OF TOTAL CANOPY COVER										200	Total
	WEIGHTED %VERTICAL FILL:										(80/2) = 40%	
	WEIGHTED PROPORTION VERTICAL FILL:										0.40	(filled /Total)

20% of the canopy cover is 1.3m deep

50% of the canopy cover is 0.9m deep

30% is 0.3m deep

To calculate the answer later, in a spreadsheet, fill in a 1 in each shaded block. Then calculate side totals and sum the number of filled squares. The sum out of 200 gives the weighted average proportional vertical fill. Example: approximately 20% of the canopy cover was c.1.3m deep, 50% was 90cm deep, and about 30% was 30cm deep, giving a weighted average proportion vertical fill of 0.4 or 40%

OPY DEPTH

2.0											0	
1.9											0	
1.8											0	
1.7											0	
1.6											0	
1.5											0	
1.4											0	
1.3	1	1									2	
1.2	1	1									2	
1.1	1	1									2	
1.0	1	1									2	
0.9	1	1	1	1	1	1	1				7	
0.8	1	1	1	1	1	1	1				7	
0.7	1	1	1	1	1	1	1				7	
0.6	1	1	1	1	1	1	1				7	The sum
0.5	1	1	1	1	1	1	1				7	= 80 cm
0.4	1	1	1	1	1	1	1				7	= avg.
0.3	1	1	1	1	1	1	1	1	1	1	10	Wt'd
0.2	1	1	1	1	1	1	1	1	1	1	10	canopy
0.1	1	1	1	1	1	1	1	1	1	1	10	depth
0.0	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	80	Filled
	% OF TOTAL CANOPY COVER										200	Total

WEIGHTED PROPORTION VERTICAL FILL: **0.4** ***(filled /Total)***

Things to remember: *(some points are repeats from section D 1)*

- In general, if one plant occurs under another, do not add their canopy depths together – find the average of individual plant canopy depths (or treat each level as a separate layer).

- If many small plants occur under large ones (e.g. herbs under trees), assess the average canopy depth and canopy cover and average of these plants separately, as a separate layer. Assessing different kinds of plants as separate layers often makes the assessment easier. 3 layers are provided for (e.g., a tall tree layer, a shrub/bush layer, and a herb layer), but more can be used.

- If the canopies of the "understory" meet and intermix with the canopies of the "overstory" or upper browse layer such as in a dense bush clump, it can be difficult to work out where on layer begins and the other ends. In this case, treat the entire bundle as one canopy. The entire bundle's canopy depth needs to be judged as one unit, combining the depths of the upper and underneath plant canopies. Do account for unfilled spaces e.g. near the ground (don't just assume a full of 2m fill!)

- Sometimes bushes may have a domed shape where the outer layer contains all the available leaves and twigs, while the inner section contains inedible thick branches, dead twigs and no leaves. In these cases, try to estimate the average thickness of the browsable layer itself (which curves over the bush) and not the apparent height of the whole bush. Some climbers / creepers can also form a thick layered tangle over vegetation, where the underneath sections contain no available browse while a surface layer of browsable material covers the tangle. Take the depth of this surface layer only.

3. The canopy cover, expressed as a proportion from 0 to1, is multiplied by the proportion of vertical fill

Proportion BA = Proportion Canopy Cover x Proportion Vertical Fill

Proportion BA x 100 = % BA

E.g. 10% canopy cover x 25% vertical fill = 0.1 x 0.25 = 0.025 =2.5%.

IMPORTANT: Remember to get the decimal places in the right place
when converting from %'s to proportions,

e.g. 0.5% = 0.005, 5% = 0.05, 50% = 0.5

4. Add the % BA's of any vegetation components assessed separately

For example, add the BA scores for the woody and herb components, or any other subdivisions of vegetation in a plot.

% BA(woody) + %BA(herb) = Total % BA

or

% BA(component A) + %BA(component B)…etc = Total % BA

- If the components were assessed by dividing the plot area into sections, you need to calculate an *area-weighted sum* of the component BAs – i.e. weighted by the proportion of the plot they comprised.
  - [proportion BA of component A) x proportion of .plot area(of component A)] + [proportion BA(component B) x proportion of plot area(component B)]+…etc = Total wt'd prop. BA

5. The total % BA obtained by this method is then placed in the appropriate BA score category (i.e. 2 to 5% in the example used above).

The Browse Availability Score scale is as follows:

0 to 0.5% mid 0.25%	**15% to 20%% mid 17.5%**
0.5 to 1%% mid 0.75%	**20% to 30%% mid 25%**
1% to 2%% mid 1.5%	**30% to 40 %% mid 35%**
2% to 5%% mid 3.5%	**40% to 50%% mid 45%**
5% to 10%% mid 7.5%	**50% to 60%% mid 55%**
10% to 15%% mid 12.5%	**60% to 70%% mid 65%**
	>70%% mid 85%

6. Calculating an overall Browse Availability Score for a property

The overall browse availability score for a vegetation type (or sub-type*) is the average of the BA scores given to plots assessed within that type, placed in to the appropriate BA score class.

The overall Browse Availability Score for the protected area is calculated as the sum of the mid-point value of each vegetation type's BA score (expressed as a proportion from 0-1) x by the proportional area of each vegetation type. [The BrCCModel's DataInput file will automatically calculate the overall BA score for a reserve if you enter the scores and proportional area for each vegetation type]

Example of calculating the total BA score for an area:

Vegetation Type	BA Score	BA mid-class	% of Reserve	BA~mid as proportion	Area as proportion	*BA x Area*
Riverine Woodland	20-30%	25%	8%	0.25	0.08	0.02
Combretum Veld	2-5%	3.5%	64%	0.035	0.64	0.022
Acacia Karroo Thicket	40-50%	45%	28%	0.45	0.28	0.126
				TOTAL RESERVE BA Score:		***0.17***

This 0.17 or 17% represents the average degree to which the 0-2m space across the entire reserve / property is filled with browse.

Estimates from some real examples:

Western Kunene, a desert area, has average BA in the range of 2 to 5%,

Vaalbos National Park has around 20%

Hluhluwe Game Reserve has an estimated BA of 25-30%

Ndumu Game Reserve has around 35%

Pilanesberg National Park has around 10-15% available browse.

When BA score data is combined with information on the ***suitability*** of that browse for black rhino, *it gives a strong indication of the potential of an area to carry black rhino*.

7. Survey designs

Time of year for field assessments

The visual browse availability assessment technique is reasonably robust in dealing with seasonal variations in standing available browse for the woody browse component. This is because the main structural parts of woody plants, which provide the skeletons for assessing browse volume, remain similar irrespective of the amount of leaf material present on them. A measurement variation of around 10cm on average per plant for each canopy spatial dimension will probably result from dry-season leaf drop.

The herb component however does exhibit large seasonal fluctuations in available volume. The assessment of herb BA will need to represent an average situation between wet and dry season conditions.

For this reason, in southern Africa, early dry season (approximately April / May / June depending on the length of the wet season in the region concerned) is the best time to survey black rhino browse availability, if only one survey in a year can take place. This time of year provides indications of both wet season and dry season browse conditions (i.e. a reasonable average of these).

If two surveys can be done, one should be in peak summer and one in mid-late winter after leaf drop but before the main leaf flush. Assessment only in full summer is not advised, as it would be difficult to account for the decline in browse availability of the late dry season.

Survey layout

Stratification

A stratified survey of an area is usually the only practical means of sampling all the vegetation available to rhino. Stratification is by vegetation type – i.e. species composition and density / size structure. *A vegetation map of the property to be assessed is essential*, because it s important to visit and assess all the different kinds of vegetations available to rhino. Aerial photographs are also highly recommended to assist with stratification within broad vegetation types. If no vegetation map is available, the assessor needs to obtain a 1:50 000 topocadastral map or something similar, and needs to work closely with someone who knows the area well. With this person's help, before (and perhaps during) the survey, a rough vegetation map needs to be drawn up. Features such as different orders of drainage line, hill side etc can easily be delineated to form the first "vegetation types".

For variance-reduction purposes, it is especially important to identify and estimate proportions of thickets or bush clumps within vegetation types – these will need to assessed as "vegetation strata" on their own. Such clumps are usually "outliers" in generally lower-density vegetation strata, and hugely inflate the variance and sample-size requirements for such strata. They are best dealt with separately. Similarly, in otherwise dense thicket vegetation types, open pan sites need to be treated separately. Vegetation types can be also be subdivided on the map if some parts are in very different size-structure states to other parts. If this is done, then such subdivisions get treated as separate vegetation "types". They will need to be rated for average BA score, and their proportional area must be calculated.

Example: you may estimate that bush clumps make up 7% of the area within a vegetation type called "*Terminalia / Burkea* Woodland", and this type comprises 46% of the entire property. Thus bush clumps make up 7% x 46% or 0.07 x 0.46 = 0.032, or 3.2% of the entire property, and the "*Terminalia / Burkea* Woodland" without clumps makes up 46% - 3.2% = 42.8% of the property.

The degree to which one tries to stratify for thickets etc will have to be based on what can be practically recognised and surveyed in the field.

Conducting a proper scientific survey

Ideally (if time/ resources permit), a properly designed survey with stratified systematic or random samples within each vegetation type should be conducted. By recording the GPS position and taking photographs from 2 different sides of each sample plot, *this survey can act as a valuable baseline of browse conditions in an area, against which subsequent browse availability changes can be monitored in a rhino area*. ***Date sheets*** *for browse availability surveying are provided in appendix 2 A, while appendix 2 B can be used to rate species contribution to available browse.(see later for use of sheet B*).

Sample size – number of plots

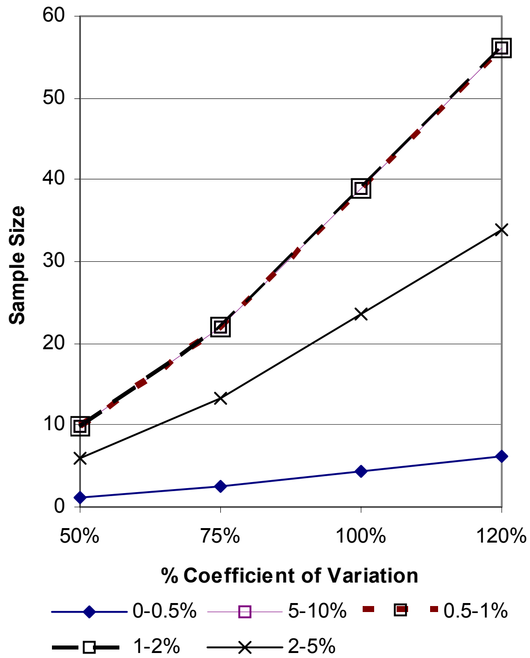
The number of plots to assess in each vegetation type depends on the degree of variation in browse availability within a type. More variable types need a greater number of samples. Very dense vegetation types tend to need more sampling than others, partly because the desired confidence intervals are closer to the score mid-class, as a % of that mid-class (i.e. you are attempting to be proportionately more accurate in thicker vegetation types).

If you can perform a pilot survey to obtain estimates of vegetation type average BA scores and sample standard deviations, you can determine the sample % coefficients of variation (Std.Dev./Mean x 100), and then your sample size requirements for each vegetation type using the graphs below.

Some rules of thumb provided by previous surveys are given in the table below. For homogeneously very open vegetation (<1% BA), generally <20 samples may be needed. For most other types in the range 1 to 30% BA, around 25 samples are generally needed. For large areas of thicket (BA > 30% on average), 50 samples may be needed, but fewer will be needed for thicket patches and bush clumps which occur as a small% area within generally more open vegetation types.

Example % coefficients of variation obtained in 5 vegetation types.

	Open *A.seberiana* Woodland	**Bushveld**	**Riverine**	**Thornveld**	**Mahemane Thicket**
Avg. BA Score,	0-0.5%	5-10%	10-15%	5-10%	40-50%
Mid-Class	0.25%	7.5%	12.5%	7.5%	45%
%CV without thicket patches		80%	48%	80%	Excl. open pans. 35%
Sample size needed	c.5	c.25	c.25	c.25	c.40



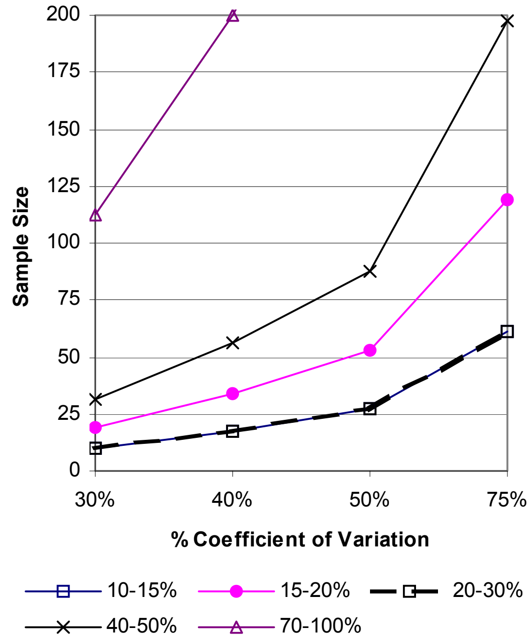


Figure 9: Sample sizes requirements for a range of average %BA's (see key) and % CV's (e.g. if you estimated CV is 100% and your estimates average BA score is 2-5%, you will need c. 24 sample plots in that vegetation type for proper statistical inference).

Plot sizes to assess:

- Square or circular plot can be used (circular plots of a given diameter ***d*** are equal to 78.5% of the area of a square plot with sides = length ***d).***
- Maintain the same plot size within the same vegetation type/stratum.
- The "pie" volume being assessed is the plot ground area x 2m height, e.g. for a 20m diameter circular plot, the volume is 314.16m^2 x 2m = 628.32m^3.

Square Plots (Ground area)	Type of Bush Density	Circular Plots (Ground area)
5x5m = 25m^2	⇐thick bush, bush clumps, thickets⇒	5m diameter = 19.6m^2
10x10m = 100m^2		10m diameter = 78.5m^2
20x20m = 400m^2	⇐moderate to fairly open bush density⇒	20m diameter = 314.2m^2
40x40m = 1600m^2	⇐desert, grasslands and very open bush⇒	40m diameter = 1256.6m^2

Conducting a rapid survey

Where time and funds do not permit a proper scientific survey, a more rapid eye-balling approach will have to be adopted. During such a survey, the assessor must plan a walked+ driven route to visit as many patches or sections of each vegetation type as possible during the time available, using a vegetation map. It is important to get good evaluations of riverine or drainage line areas.

Instead of doing proper plots, treat each visited patch or section of a given vegetation type as a sample "site", and use datasheets in appendix 2 A, and 2C (which rates proportional species composition of the available browse).

Estimate the average browse availability (as per this technique) more widely across a field of view within a given vegetation type at the site. The calibrated browse availability photographs* can be used to assist with rating – this will also speed up assessments.

If you have difficulty assigning a single average %BA score, you can deal with vegetation variability or your uncertainty about the exact average %BA score, by assigning probabilities between 0 and 1 of different %BA classes being relevant to the site, and use the appendix 2. 2 B datasheet (you can use appendix 2 A and 2 B datasheets for the same site – just number the sites correctly on each).

See the table and examples below for an explanation.

** calibrated browse availability photographs from 6 southern African reserves are supplied on disk. A set showing comparable forms of vegetation to the area to be assessed, covering a range of browse availabilities, should be printed out in good quality colour, and laminated for use in the field.*

For example, in ***case A*** (see table below) when unsure of correct score: you may estimate that a site probably has an average score of 2-5% - you feel you are about 75% sure of this, however, you feel there is about a 25% chance that it is 1-2% on average.

- Enter 0.75 into the prop.? column in the 2-5% BA row
- Enter 0.25 into the prop.? column in the 1-2% BA row
- Multiply 0.75 by the mid-class proportion 0.035 for that BA class, place answer 0.2625 in the next column Wt'd Avg.
- Multiply 0.25 by the mid-class proportion 0.015 for that BA class, place answer 0.00375 in the next column Wt'd Avg.
- Sum these proportions in the bottom block: weighted average answer **0.03 or 3%.**

Site / Plot No.: **Vegetation Type:**		Case A Hilltop grassland		Case B Xerocline Slope	
BA Score	**Mid-class proportion**	**Prop?** (Un certain)	**Wt'd Avg.**	**Prop?** (variable Veg)	**Wt'd Avg.**
0-0.5%	x 0.0025				
0.5-1%	x 0.0075				
1-2%	x 0.015	0.25	0.00375		
2-5%	x 0.035	0.75	0.02625	0.25	0.00875
5-10%	x 0.075			0.3	0.0225
10-15%	x 0.125			0.3	0.0375
15-20%	x 0.175				
20-30%	x 0.25			0.15	0.0375

30-40%	x 0.35				
40-50%	x 0.45				
50-60%	x 0.55				
60-70%	x 0.65				
70-100%	x 0.85				
	Sum->		0.03 3%		0.106 10.6%

For example ***case B*** (see table above) when the vegetation site is fairly patchy and variable in amount of browse: you may proceed to estimate scores for separate subtypes and estimate what proportion each subtype comprises in that site: i.e. 25% of the site scores 2-5%, 30% scores 5-10%, 30% scores 10-15%, and about 15% scores 20-40%.

- Enter 0.25 into the prop.? column in the 2-5% BA row
- Enter 0.3 into the prop.? column in the 5-10% BA row
- Enter 0.3 into the prop.? column in the 10-15% BA row
- Enter 0.15 into the prop.? column in the 20-30% BA row
- Multiply each of your entered proportions by the corresponding mid-class proportion, placing the answer in the next column Wt'd Avg.
- Sum these proportions in the bottom block: answer **0.106 or weighted average 10.6%**

Using your final recorded scores for each site visited within a vegetation type, try to gain an integrated impression of the average BA of each vegetation type as the survey progresses. In the end, enough of the diversity of states or conditions within each vegetation type must be visited and evaluated to give a valid overall average browse availability score for each type. You can use your site assessments within sections of a vegetation type to get an average estimate for the entire vegetation type.

Important Note: Observers tend to overestimate browse availability using only the photographs, *thus when allocating final %BA's for each vegetation type using photographs alone, use the lower boundary of the BA score class that the relevant photo fell into.* For example, if you estimated that vegetation type A matched photos showing 28% browse- i.e. from the BA score class 20-30% browse, use 20% as you final allocation, not the BA score mid class of 25%.

To calculate the overall park browse availability, see section C6, but use your actual final scores for each vegetation type – *do not now use the relevant %BA score mid-classes*.

While this is not a rigorous scientific approach, it can still provide ballpark BA estimates to assist carrying capacity estimation. It is valuable to conduct the survey with someone who knows the area well. This allows such a person to bring their knowledge of the overall vegetation conditions to bear when deciding jointly on average BA scores for vegetation types.

Assessing plant species contribution to available browse
(datasheet from appendix 2C)

Once % browse availability has been assigned to a plot or site, one should proceed to assess the different plant species' contributions to this available browse. This amounts to estimating what proportion or percentage of the available browse biomass made up by each species present in the plot. Later, this data is combined with ratings of each species' value to potential black rhino diet. This allows a more objective assessment of the overall suitability of the available browse for black rhino in each vegetation type. Browse suitability is also a determinant of black rhino carrying capacity.

The issues of assessing species contribution to available browse, and determining objective ratings of species value to black rhino, are still under more detailed investigation. Also, better information on the diet profiles and species preferences of black rhino population from a large range of habitats is still accumulating. A rough approach is outlined here.

The basic field approach is similar to the dry-weight-rank method of t'Mannetje and Haydock (1963), but adapted for browse.

- In a plot or site, the species which contributes most to the available browse is ranked 1, the next most is ranked 2 etc. Species can share a rank if their biomass is similar.
- Try to rank at least the first 5 species.
- For other species present in smaller but still noticeable amounts, place a "+" in the data column opposite their name.
- Use a "species" called "other" to assign remaining biomass not covered by the noticeable (i.e. listed) species, as described below.
- Next, for the ranked species, estimate approximately what % each species contributes to the available browse. Assign %'s at least to the species which together make up 80% of available browse. In some cases this may only be one or two species, which is fine. Also specify a % for " _ species" and "other" to show how much browse resides with each of these classes of plant species.
- Don't fuss about getting the summed %'s correct (i.e. to sum exactly to 100%) but try to get the correct relative difference in amount between the ranked species correct. You can always re-scale the values given later, to sum to the correct amount.
- Occasionally a plot may contain many species, and %'s become difficult to assign. Just rank the species as best you can, assign a % contribution to the first 1 or 2 species, and later create a decreasing % biomass allocation scale based on these ranks.

Field Sheet	Plot 1		Plot 2		Plot 2-% re-scaled to sum to 100%
Species	**Rank**	**%**	**Rank**	**%**	
Acacia tortilis	1	50%	+		1.7%
Ozoroa engleri	+		2	10%	11.1%
Barleria taitensis	4	5%			
Combretum molle	2	25%	4	5%	5.6%
Colophospermum mopane	3	10%	2	10%	11.1%
Maytenus senegalensis	5	3%	1	50%	55.6%
Ziziohus mucronata	+		+		1.7%
Tarconanthus camphorates			3	7%	7.8%
Total % for + Species		2%		3%	-
Total for Other Species		5		5%	5.6%

- These data should be entered on a spreadsheet after the survey is complete. Species given a + need to have the total for + species divided among them equally.

- Next, rescale your % to add up to 100%. This is done by summing all the assigned %'s, and then for each species (or other) dividing its % by this total.
  For example, in plot 2 above, the assigned %'s add to 90%. Results of re-scaling these to add to 100% are shown in the right hand column, e.g. *Ozoroa was 10% of 90% = 11.1%*

- Next, an actual %BA score is assigned to each species listed in the plot, by taking the % of each species / 100 and multiplying this with the assigned plot %BA.
  For example if plot 1 had an overall woody %BA of 25%, then
  Acacia tortilis had a %BA of 25% x 0.5 = 12.5%,
  Maytenus senegalensis had a % BA of 25% x 0.03 = 0.75%.

- The average "actual" %BA (browse availability) of each species within each vegetation type can then be calculated as its average %BA across all plots surveyed within a vegetation type.

To get final browse suitabilities for each vegetation type:

- Each species is assigned a suitability score from 1(low) to 3(high), which reflects a combination of importance and preference in rhino diet (a comprehensive list with ratings based on multiple feeding studies across southern Africa is being prepared).

- Sum the final average % BA of all species ranked as 3 (high) within a vegetation type.

- This is an index of the absolute amount of browse in that vegetation type that is suitable rhino food.

- Now: take this summed %BA score for suitable browse species, and divide it by the overall average %BA score for that vegetation type. *The resulting proportion represents the degree to which the vegetation is suitable for black rhino*.

- This answer can be translated into the low to high suitability scale for input into the black rhino carrying capacity model.

E: BACKGROUND AND JUSTIFICATION FOR THE BLACK RHINO BROWSE AVAILABILITY SCORE METHOD

The need for an easily implemented, standardised black rhino-specific browse availability assessment procedure arises from the black rhino conservation plans of several African countries. These specify the need to create new rhino populations in new habitats with acceptable carrying capacities for this species. The plans also require that existing rhino areas are managed for maximum productivity, by maintaining rhino densities below the maximum level supported by the vegetation resources.

Assessments of available rhino browse are integral to carrying capacity assessments that assist in deciding potential rhino densities and rhino introduction numbers for new areas. They can also aid in the describing or ongoing monitoring of habitat conditions in existing rhino areas, under conditions of changing climate, vegetation and competing browser densities. Standardising browse availability assessment across all southern African black rhino areas also assists in developing our understanding of contrasting black rhino habitat conditions and related population performances across the sub-continent.

The need for a quick, but acceptably accurate method to estimate the amounts of available forage (e.g. browse) across large areas of land and in different habitats, is widely recognised in the endeavour of assessing animal carrying capacities. Direct methods involving destructive sampling and weighing of browsable plant parts are expensive and impossible to use routinely in most situations. Indeed, Blair (1958) stated that browse biomass is recognised as one of the most difficult of all vegetation components to measure.

Allometric regression methods: evidence for the strong relationships between browse availability and plant dimensions

Efficient ways of estimating available browse and other attributes such as plant biomass, leaf area and fuel wood, have been extensively investigated (e.g. Netshiluvi and Scholes 2000). These approaches involve determining the mathematical (allometric or morphometric) relationship between more easily measured aspects of plant size and the target attribute. The basis for this is the necessary physical relationships between a plant's size and its aboveground biomass; and between the leaf or shoot mass or leaf area that can be supported and the cross-sectional area the stem which supplies them with water.

Regression equations for predicting woody plant biomass from plant height and/or basal stem circumference for 23 different southern African trees showed highly significant r-squared's of near or > 0.95 (Netshiluvi and Scholes 2000). Equations for predicting leaf or shoot mass (browsable material) from plant height and/or basal diameter or circumference for 23 different southern African trees or tree classes* also showed highly significant r-squared's of much greater than or >= 0.85 (Netshiluvi and Scholes 2000). Allometric regressions of canopy diameter on seasonal production of leaves and twigs by Kelly and Walker (1976) also showed highly significant r-squared's in 8 lowveld species in Zimbabwe.

*e.g. combined *Acacias,* broadleaves, *Brachystegia* species, mixed-species scrublands and woodlands in Botswana.

Although the above highly significant regressions bring validity to indirect measures as a surrogate or index of available browse, in many field situations, plant height, canopy structures and available browse may be altered by continuous browse pressure (e.g. impala browsing in riverine areas of Kruger National Park, Dayton 1978), animal damage, or fire.

This means that browse canopies do not always closely conform to the general patterns for a given species. Also, parts of a canopy may be out of reach of certain browsers. Use of simple canopy area, basal stem measurements and even plant height cannot provide realistic reflections of this diversity in browsable plant canopy.

Methods focussing in greater detail on the plant canopies within browsable height are more appropriate. Such methods aim at closely measuring plant canopy shape, for example in the BECVOL method of Smit (1996). Smit (1989), demonstrated highly significant correlations between the volumes of the canopy sections being measured and the leaf mass contained within the volumes, corrected for apparent leaf density visually assigned on a scale of 1 (sparse) to 3 (dense) (e.g. r^2's from linear regression of 0.93 to 0.98 were found for the microphyllous *A.karroo*, and *D.cinerea* and the non-microphyllous *Grewia flava.* R^2's of 0.88, still highly significant, were obtained without the visual correction for apparent leaf density).

Others have also shown highly significant log-log or quadratic relationships between more crudely measured available canopy volumes and browse forage production for a range of shrub species. (e.g. Bryant and Kothmann (1979), Hughes et. al. (1987). These authors' and Smit's regressions were species specific, nevertheless, common multi-species equations also show that significant relationships exist.

A problem with these methods is that they still require detailed and time-consuming measurement of individual plant canopy dimensions. This leads to problems in the ability to sample many vegetation sites, as too much time is spent in relatively few sites. Given the naturally great variability in vegetation physiognomy within any single protected area, sampling available browse via relatively fewer accurately measured plots is inferior to assessing many sites at an acceptably lower precision (e.g. as highlighted by Haydock and Shaw, 1975).

Visual estimation methods

In seeking a viable approach allowing for more rapid, widespread sampling, visual assessment techniques have been proposed. In grasslands, herbage availability (yield) can efficiently be estimated in random sites (quadrats) by visually rating these sites with respect to a set of reference sites, which provide a scale over a range of availabilities (yields) Haydock and Shaw, 1975.

In a study of the browser carrying capacity of eastern Cape succulent valley bushveld, Stuart-Hill (1991), Stuart-Hill and Aucamp (1993) developed a visual browse vegetation "condition" index using reference "visual calibration" sites, which represented to a large extent the range in available browse from very dense thicket to sparse woody vegetation. This index however also accounted for differences in dominant plant species palatabilities, so that the condition index required the simultaneous assessment of two parameters, availability and suitability. Their experimental trials with goat browsers demonstrated the positive (but possibly curvilinear) relationship between the condition index and browse capacity, with a c.27-fold increase in carrying capacity from the least to the most dense vegetation conditions.

Given the evidence above for strong relationships between various plant canopy dimensions (volumes) and leaf/shoot material available to browsers, a visual approach that focuses on plant canopy attributes seems highly appropriate in browse availability assessment for black rhino.

DEVELOPMENT OF THE BLACK RHINO BROWSE AVAILABILITY SCORE METHOD

Browse availability had previously been separated from browse palatability or suitability as a separate variable with its own strong influence on black rhino carrying capacity. For example in the RMG Black Rhino Carrying Capacity Model Version 1 (Adcock 2001), highly significant correlations were found between expert estimates of rhino carrying capacity and the square root of the first visually-based browse availability index developed for the model. Similarly, strong correlations were found between the index and the log of average male home range size across 15 rhino areas (correlation coefficients were 0.77 and -0.81 respectively). Assessing a single parameter at a time in a visual assessment also improves the repeatability of the technique over multi-parameter visual estimation.

Defining available rhino browse: black rhino feeding heights

Possibly 98% of black rhino food comes from the 0-2m height range, and in general browse material above this level is unavailable to black rhino. Several studies have shown how most black rhino feeding is done in the 0-2m height range, and how lower feeding heights are preferred.

Percentage of black rhino feeding that occurred at different height levels in the available vegetation:

Study:		<50cm	50cm-1m	1-2m	cumulative <=2m	>2m
Breebart (2000)	Weenen	c.38%	c.47%	c. 14.4	99.4%	0.6%
Rossouw (1998)	E.Shores	35.59 %	54.45%	8.79%	98.82%	1.17%
(Joubert and Eloff 1971)	Etosha West	Optimum feeding ht. 60-120cm; with a c. 152cm (5ft) browse line (i.e. most feeding offtake was below this height level.)				

Emslie and Adcock (1993) also documented the significant decline in preference of black rhino feeding with plant height in Umfolozi. Plants of 0-1m were most preferred and taller height classes were rejected.

Black rhino can use browse from above 2m, when they can bend or push down tall plant specimens, bringing them into the <2m browse layer. This behaviour tends to be generally confined to certain preferred plant species or spindly growth forms, and does not contribute a significant proportion of total rhino food intake. Young rhino are also not readily able to access browse over 2m.

Measuring available browse volumes in defined areas, and developing calibrated browse availability photographs as an aid to visual assessment

To develop a set of *calibrated browse availability photographs* to assist visual BA assessment, canopy volumes of all plants within circular plots of known area were determined for 14 to 16 sites in 7 rhino areas covering a sub-continental range of vegetation structures and plant growth forms. There were:

	Acknowledgements
Pilanesberg National Park (April 03)	Ray Schaller
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Great Fish River Reserve (February 03)	Derek Brown

Vaalbos National Park (July 03)	Kenneth Buk
Waterberg Plateau Park (June 03)	Werner Killian
Western Kunene (June 03)	Mike Hearn
Weenen Nature Reserve (May 04)	Caiphus Khumalo

The sites in Weenen Game Reserve were also used for an inter-observer variability test of visual browse availability assessment. Results are given in *“Report on the field testing of inter-observer variability in the application of the standardised browse availability assessment method used in black rhino carrying capacity evaluation“* (Adcock, July 2004).

Plot measurements for BA assessment or photo calibration:

Canopy volumes were approximated by measuring to the nearest 10 cm the following on each woody plant:

1. lowest browsable canopy level (or average lowest level for tilted plant canopies).

2. Canopy height - up to 2m in the case of an unbendable tree, or up to 4m in the case of species / growth forms frequently broken down by black rhino.

3. Average horizontal diameter of canopy – being the mean of the average long-axis horizontal diameter and average horizontal short-axis diameter on the canopy section within reach of a black rhino. The aim here was to try to describe average canopy dimensions – i.e. not to measure the largest possible cylinder but best-fit cylinder around the canopy.

Distinct parcels of a plant’s canopy could also be measured as units in their own right in the same way, e.g. where two separate sections of canopy from a tall tree protrude down below the 2m level, or where canopy sections fall in the plot from trees rooted outside the plot.

The following were calculated from these measurements:

1. Canopy area= (average canopy diameter/2) squared x Pi

2. Canopy depth = upper canopy height or canopy height to 2m - lowest browsable canopy level

3. Canopy volume is calculated as canopy area x canopy depth = volume of a cylinder.

Volumes of all plant canopy material within the plot were summed and expressed as a % of the plot volume (2m x plot area).

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REFERENCES

Adcock K (2001). User guide to the Rhino Management Group Black Rhino Carrying Capacity Model, Version 1. *SADC Regional programme for Rhino Conservation.*

Blair RM (1958). Weight techniques for sampling browse production with special reference to deer ranges. *Symp. Proc. on Techniques and methods of measuring understory vegetation. Tifton, GA*., p1-18.

Breebaart L (2000). Resource overlap within a guild of browsing ungulates in a South African Savanna. MSc Thesis, University of Natal, Pietermaritzburg.

Bryant FC and MM Kothmann (1979). Variability in predicting edible browse from crown volume. *Journal of Range management* **32(2)**, p145-146.

Dayton BR (1978). Standing crops of dominant *Combretum* species at three browsing levels in the Kruger National Park. *Koedoe* **21**: 67-76.

Emslie RH and K Adcock (1993). Black Rhino 2000: Final Report Vol 1-5. *Ecoscot Consultancy Services, the SA Nature Foundation, the Endangered Wildlife Trust, the KwaZulu-Natal Nature Conservation Service and Total Oil (SA).*

Haydock KP and NH Shaw (1975). The comparative yield method for estimating the dry matter yield of pasture. *Australian Journal of experimental Agriculture and animal husbandry*. **Vol 15**, p663-670.

Hughes GH, LW Varner and LH Blankenship (1987). Estimating shrub production from plant dimensions. *Journal of Range management* **40(4),** p367-369.

Joubert E and Eloff FC (1971). Notes on the Ecology and Behaviour of the Black Rhinoceros *Diceros bicornis* Linn.1758 in South West Africa. *Madoqua*, **Ser. I No 3**, p5-53.

Kelly RD and BH Walker (1976). Effects of land use on the ecology of a semi-arid region in SE Rhodesia. *Journal of Ecology* **64**, p553-576.

Netshiluvi T and R Scholes (2000). Allometry of South African woodland trees. *CSIR Division of Water, Environment and Forest Technology*.

Rossouw DJ (1998). Baseline survey of dietary preferences of black rhino on the Eastern Shores of Lake St. Lucia. *B.Tech. Nature Conservation Degree thesis, Technikon Pretoria.*

Tietema T (1993). Biomass determination of fuelwood trees and bushes of Botswana, Southern Africa. *Forest Ecology and Management* **60**, p257-269.

t'Mannetje L and Haydock KP (1963). The dry-weight-rank method for the botanical analysis of pasture. *Journal of the British Grassland Society* **18**: 268-275.

Smit GN (1996). BECVOL: Biomass Estimation from Canopy VOLume (version 2) - users guide. *Unpublished manual, University of the Free State, Bloemfontein.*

Stuart-Hill (1991). Towards a visual assessment of succulent valley bushveld. *J.Grassl.Soc.South.Afr.* **8(2)**, p63-69.

Stuart-Hill GC & AJ Aucamp (1993). Carrying capacity of the succulent valley bushveld of the eastern Cape. *Afr. J. Range For. Sci.* **10(1):** p1-10.

Circular Plot of 20m Diameter (10m radius) or Square Plot of 20 x 20m						
Plant Dimensions ***(Sides of square canopies in square plot, or diameter of circular canopies in circular plot)***	***% canopy cover of a given number of plants***					
	1 plant	**10 plants**	**20 plants**	**30 plants**	**40 plants**	**80 Plants**
0.1m	0.0025%	0.03%	0.05%	0.08%	0.10%	0.20%
0.2m	0.010%	0.10%	0.20%	0.30%	0.40%	0.80%
0.25m	0.016%	0.16%	0.31%	0.47%	0.63%	1.25%
0.3m	0.023%	0.23%	0.45%	0.68%	0.90%	1.80%
0.4m	0.040%	0.40%	0.8%	1.2%	1.6%	3.2%
0.5m	0.063%	0.6%	1.3%	1.9%	2.5%	5.0%
1m	0.25%	2.5%	5.0%	7.5%	10.0%	20.0%
2m	1.00%	10.0%	20.0%	30.0%	40.0%	80.0%
3m	2.25%	22.5%	45.0%	67.5%	90.0%	
4m	4.00%	40.0%	80.0%			
5m	6.25%	62.5%				
6m	9.00%	90.0%				
8m	16.00%					
10m	25.00%					
12m	36.00%					
14m	49.00%					
16m	64.00%					
18m	81.00%					
20m	100.00%					

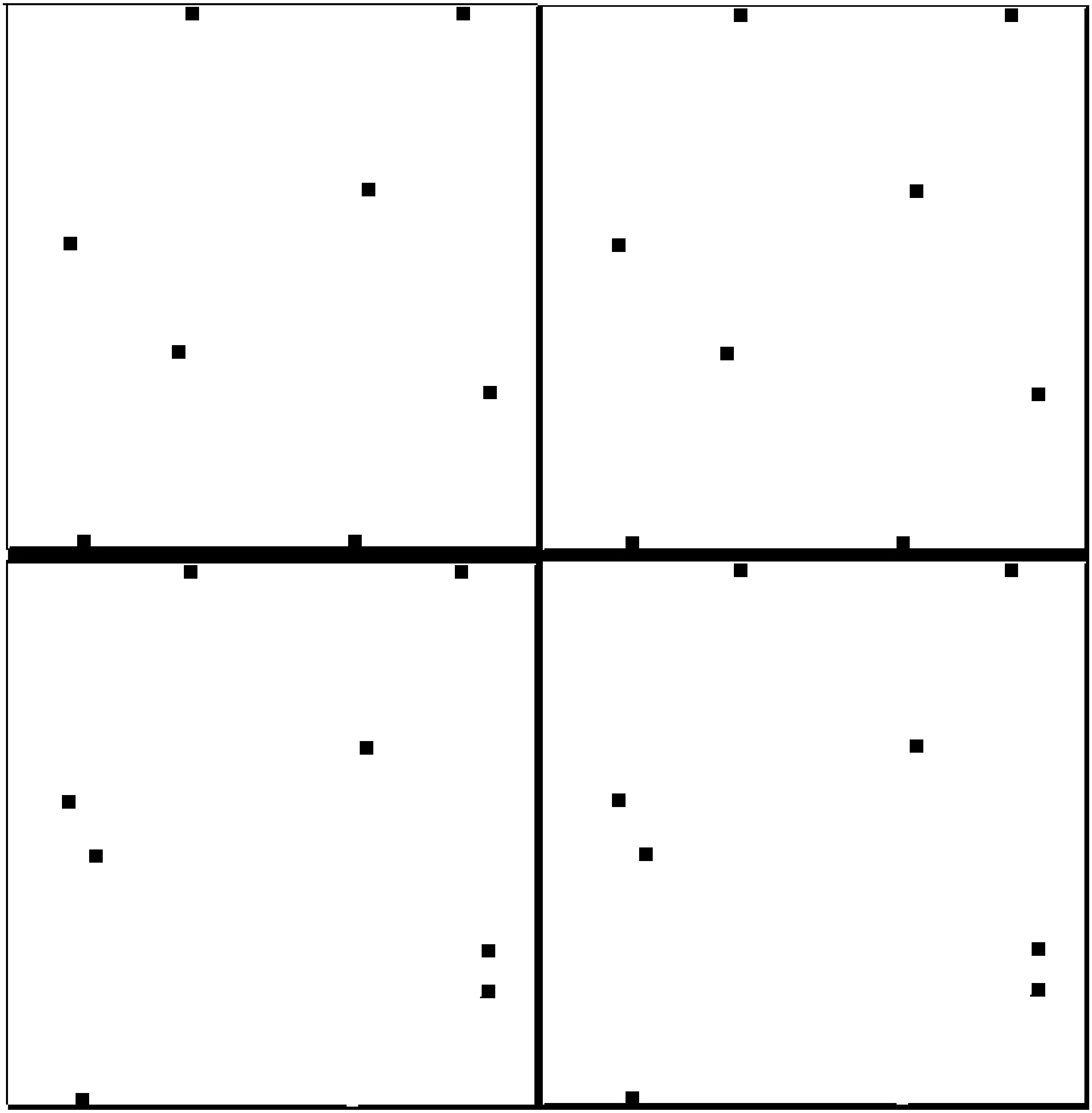
Circular Plot of 10m Diameter (5m radius) or Square Plot of 10 x 10m						
Plant Dimensions ***(Sides of square canopies in square plot, or diameter of circular canopies in circular plot)***	***% canopy cover of a given number of plants***					
	1 plant	**10 plants**	**20 plants**	**30 plants**	**40 plants**	**80 plants**
0.1m	0.010%	0.10%	0.20%	0.30%	0.40%	0.80%
0.2m	0.040%	0.40%	0.80%	1.20%	1.60%	3.20%
0.25m	0.063%	0.63%	1.25%	1.88%	2.50%	5.00%
0.3m	0.09%	0.9%	1.8%	2.7%	3.6%	7.2%
0.4m	0.16%	1.6%	3.2%	4.8%	6.4%	12.8%
0.5m	0.25%	2.5%	5.0%	7.5%	10.0%	20.0%
1m	1%	10.0%	20.0%	30.0%	40.0%	80.0%
2m	4%	40.0%	80.0%			
3m	9%	90.0%				
4m	16%					
5m	25%					
6m	36%					
8m	64%					
10m	100%					

Circular Plot of 30mDiameter (15m radius), or Square Plot of 30 x 30m						
Plant Dimensions: ***(Sides of square or Diameter of Circular plants)***	***% canopy cover of a given number of plants***					
	1 plant	**10 plants**	**20 plants**	**30 plants**	**40 plants**	**80 plants**
0.1m	0.001%	0.01%	0.02%	0.03%	0.04%	0.09%
0.2m	0.004%	0.04%	0.09%	0.13%	0.18%	0.36%
0.25m	0.007%	0.07%	0.14%	0.21%	0.28%	0.56%
0.3m	0.010%	0.1%	0.2%	0.3%	0.4%	0.8%
0.4m	0.018%	0.2%	0.4%	0.5%	0.7%	1.4%
0.5m	0.028%	0.3%	0.6%	0.8%	1.1%	2.2%
1m	0.1%	1.1%	2.2%	3.3%	4.4%	8.9%
2m	0.4%	4.4%	8.9%	13.3%	17.8%	35.6%
3m	1.0%	10.0%	20.0%	30.0%	40.0%	80.0%
4m	1.8%	17.8%	35.6%	53.3%	71.1%	
5m	2.8%	27.8%	55.6%	83.3%		
6m	4.0%	40.0%	80.0%			
8m	7.1%	71.1%				
10m	11.1%					
15m	25.0%					
20m	44.4%					
25m	69.4%					

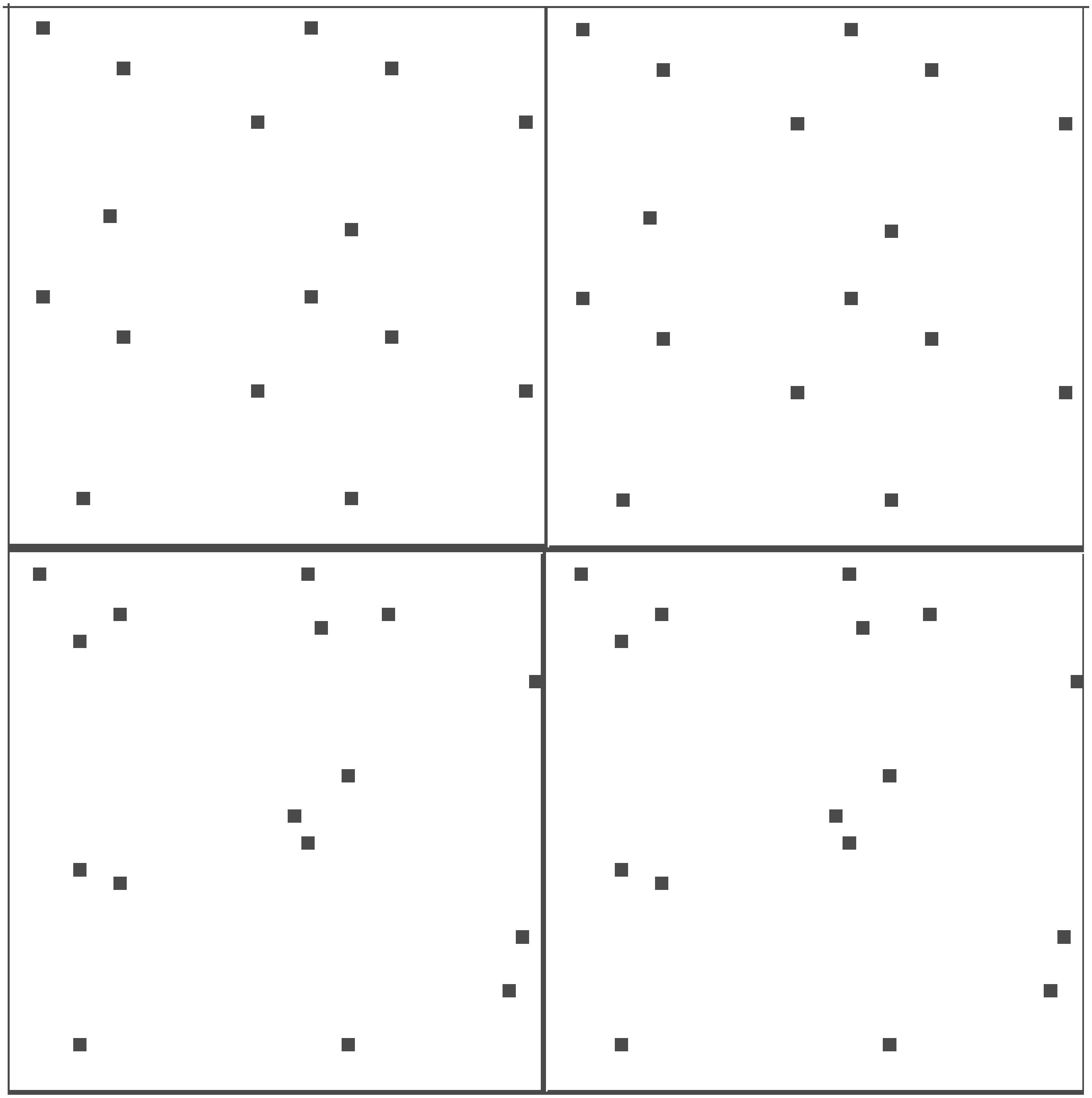
Circular Plot of 16m Diameter (8m radius), or Square Plot of 8 x 8m						
Plant Dimensions ***(Sides of square or Diameter of Circular plants)***	***% canopy cover of a given number of plants***					
	1 plant	**10 plants**	**20 plants**	**30 plants**	**40 plants**	**80 plants**
0.1m	0.004%	0.04%	0.08%	0.12%	0.16%	0.31%
0.2m	0.016%	0.16%	0.31%	0.47%	0.63%	1.25%
0.25m	0.024%	0.24%	0.49%	0.73%	0.98%	1.95%
0.3m	0.035%	0.4%	0.7%	1.1%	1.4%	2.8%
0.4m	0.063%	0.6%	1.3%	1.9%	2.5%	5.0%
0.5m	0.098%	**1.0%**	2.0%	2.9%	3.9%	7.8%
1m	0.39%	3.9%	7.8%	11.7%	15.6%	31.3%
1.5m	0.88%	8.8%	17.6%	26.4%	35.2%	70.3%
2m	1.56%	15.6%	31.3%	46.9%	62.5%	
3m	3.52%	35.2%	70.3%			
4m	6.25%	62.5%				
5m	9.8%	97.7%				
6m	14.0%					
8m	25.0%					
10m	39.1%					
15m	87.9%					

Appendix 1. % Canopy Cover Patterns, 0.5% to 90%.

0.5%



1%



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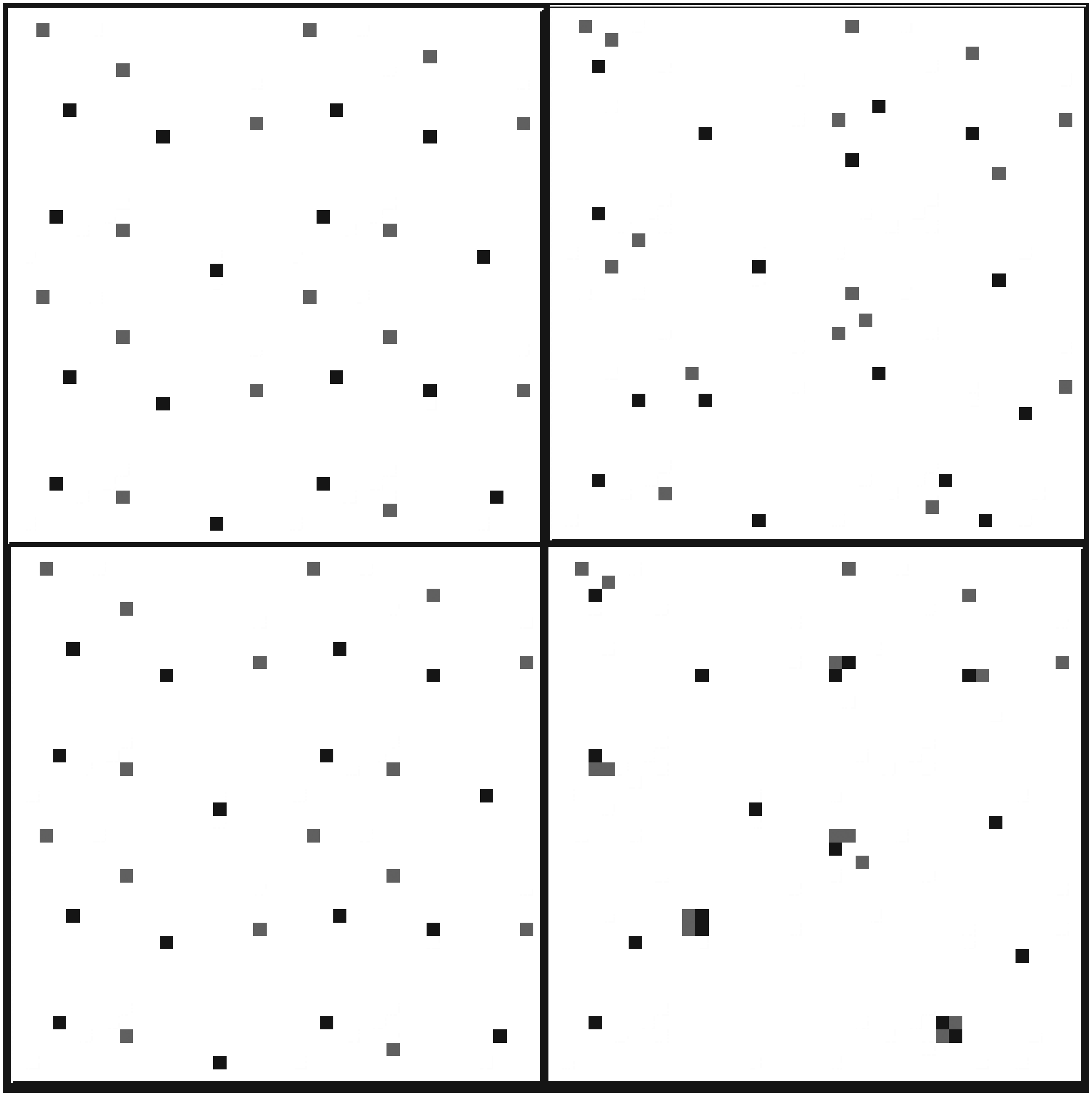

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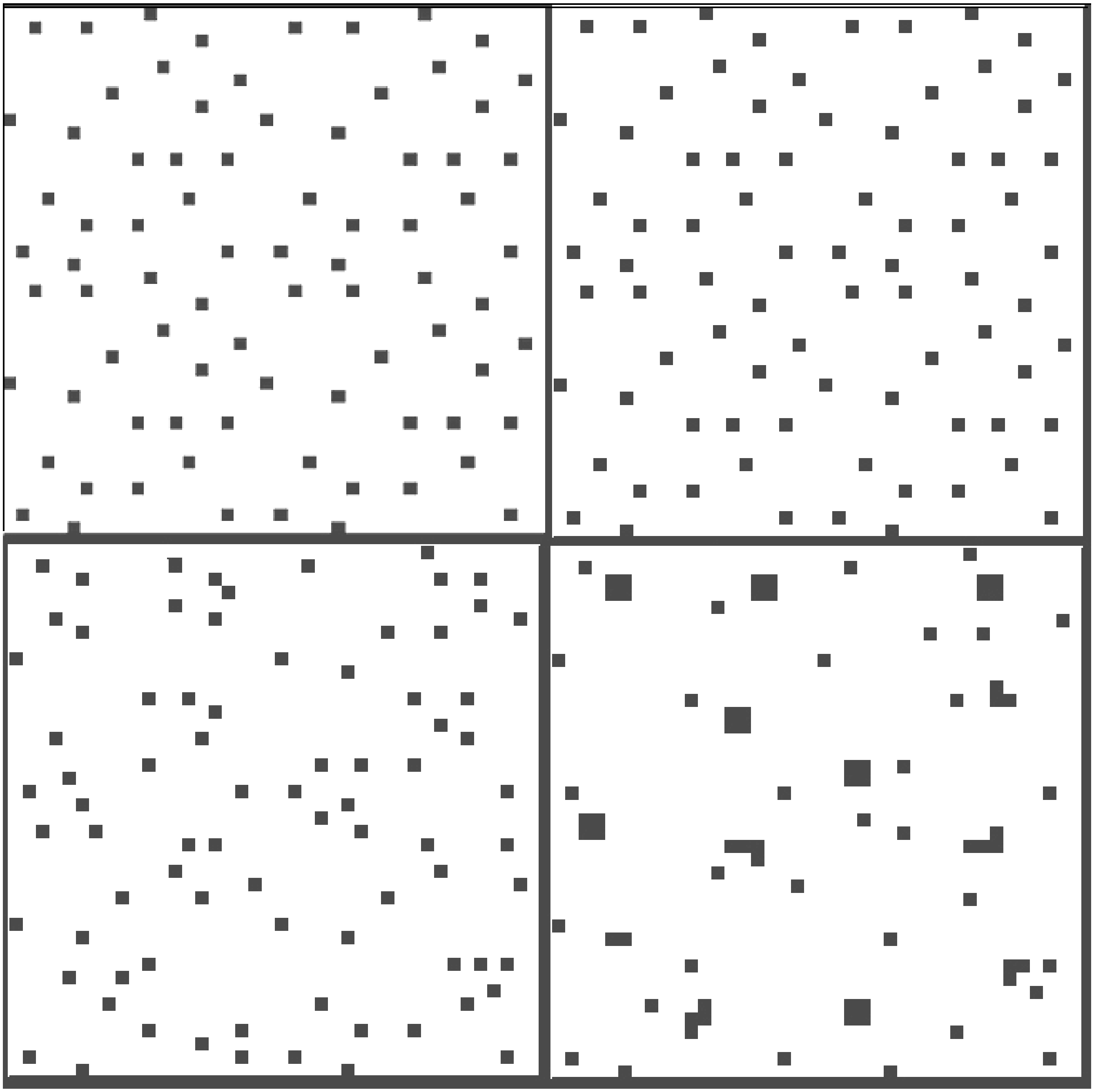

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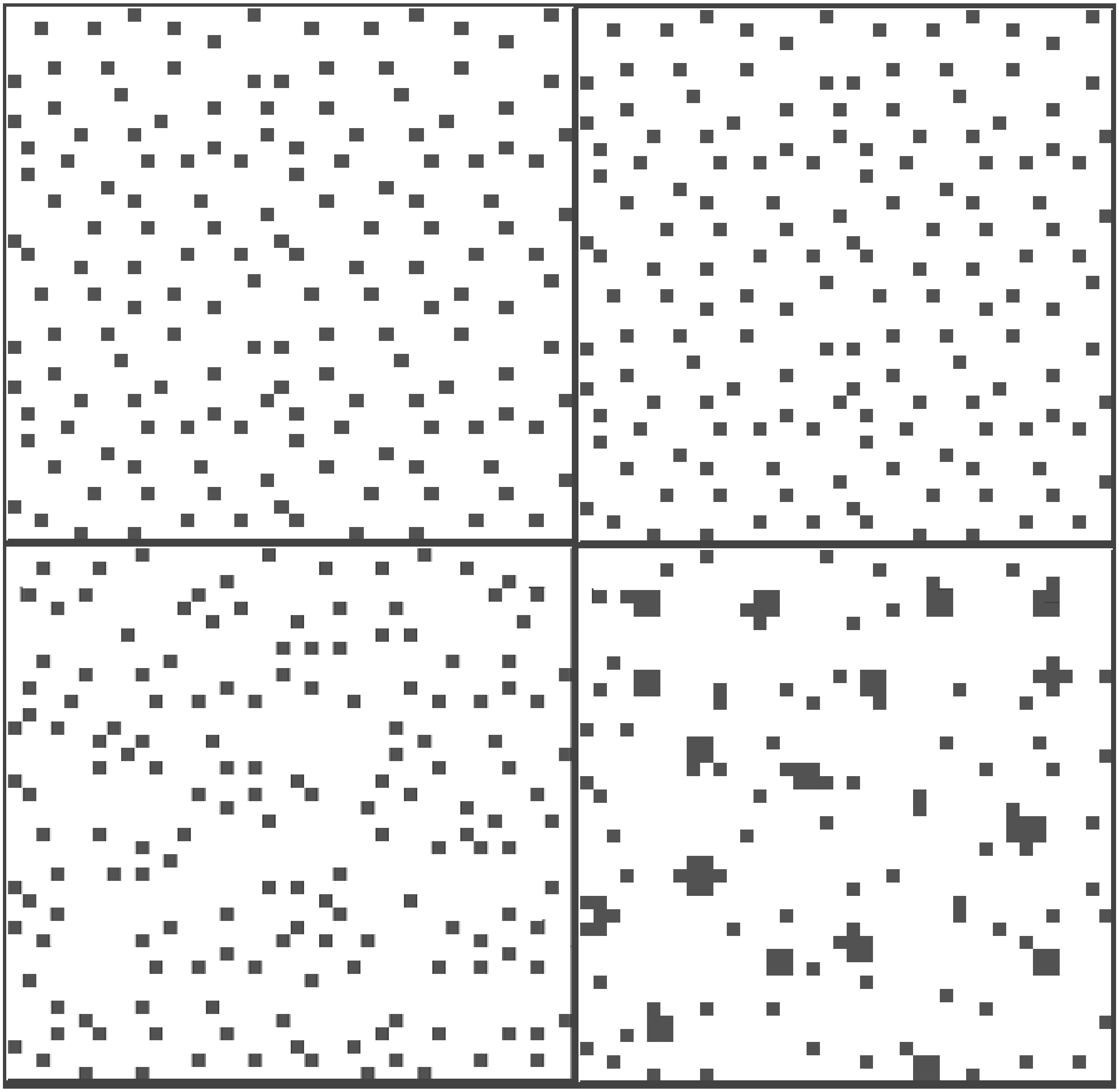

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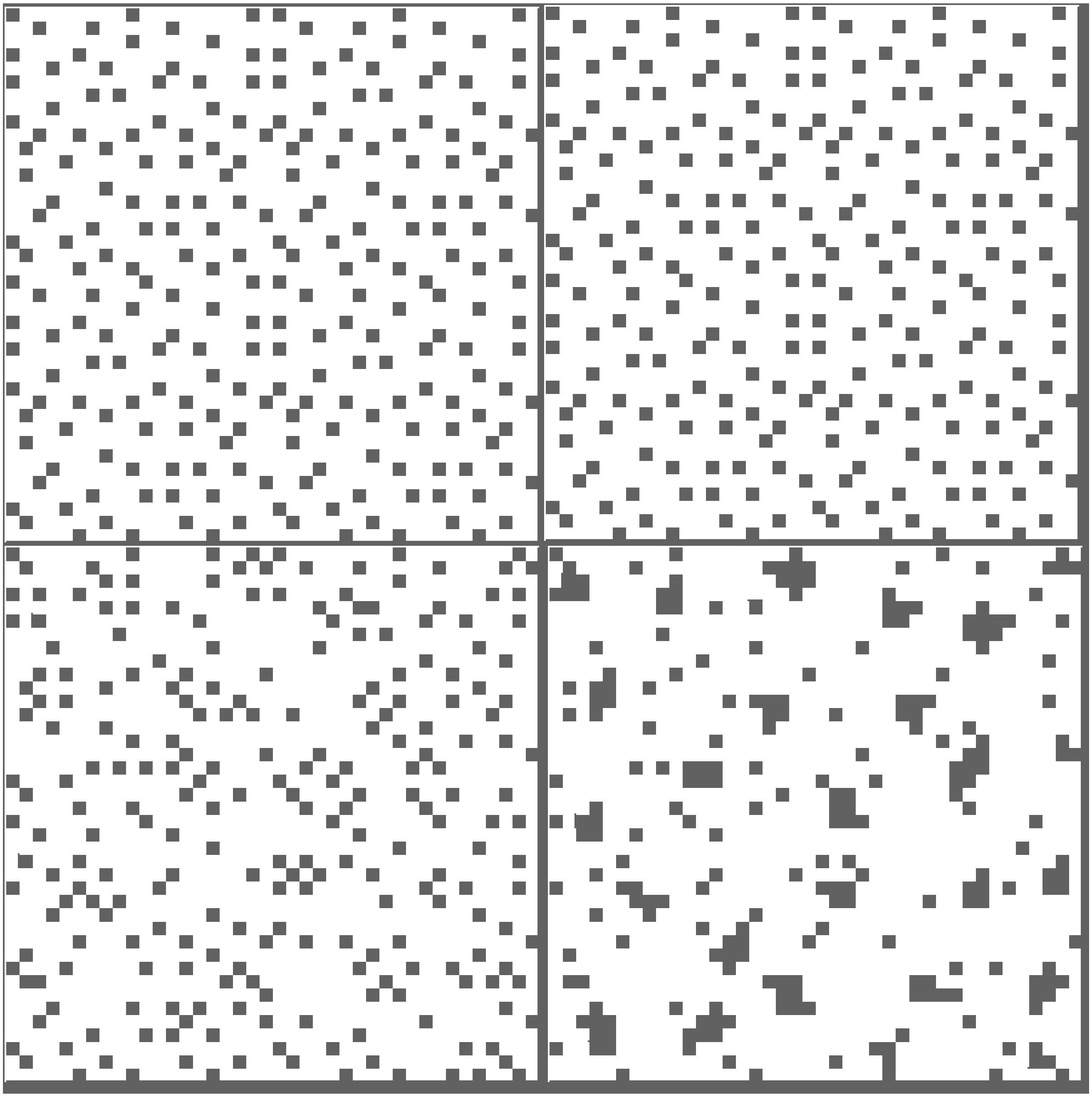
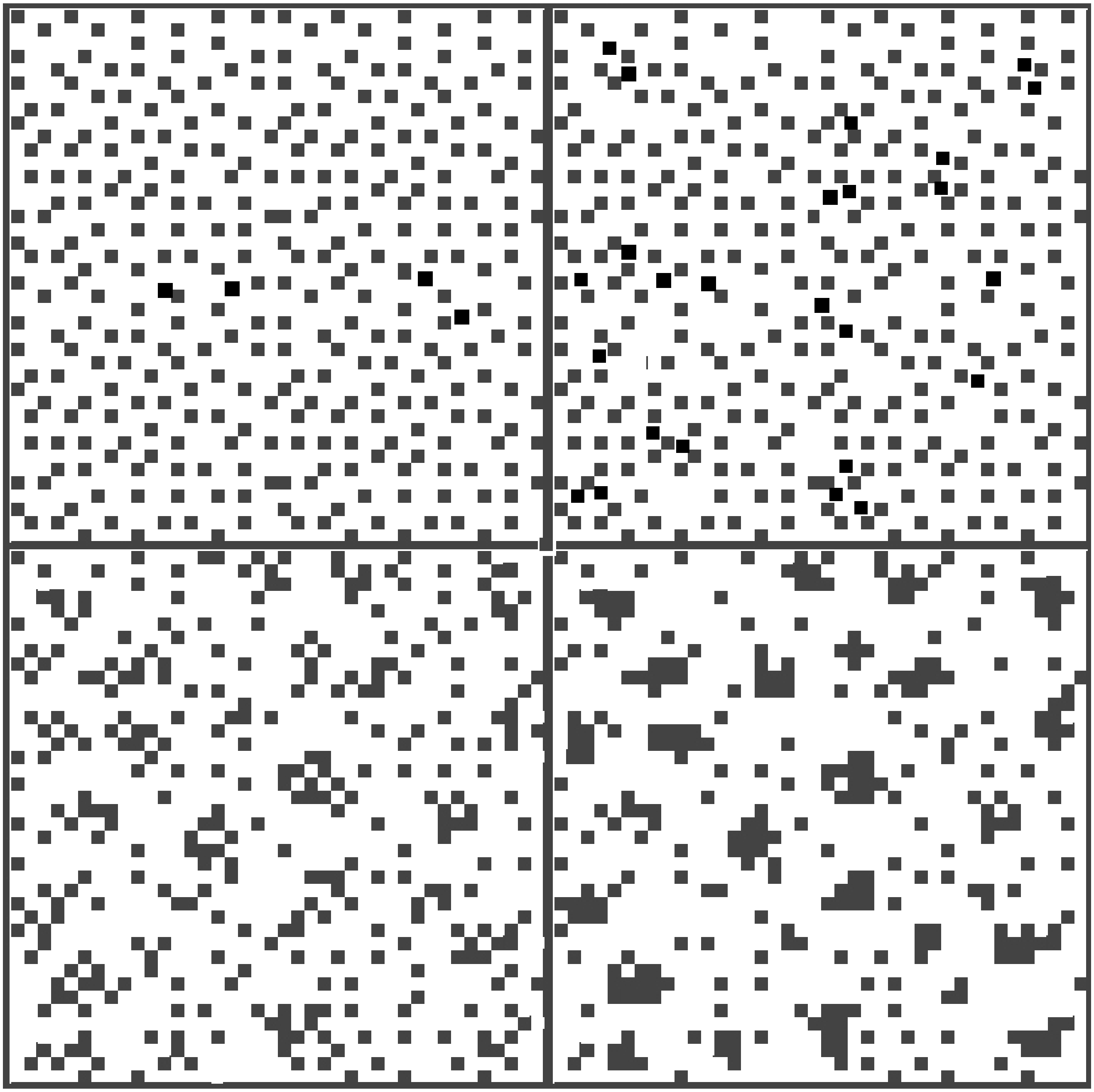
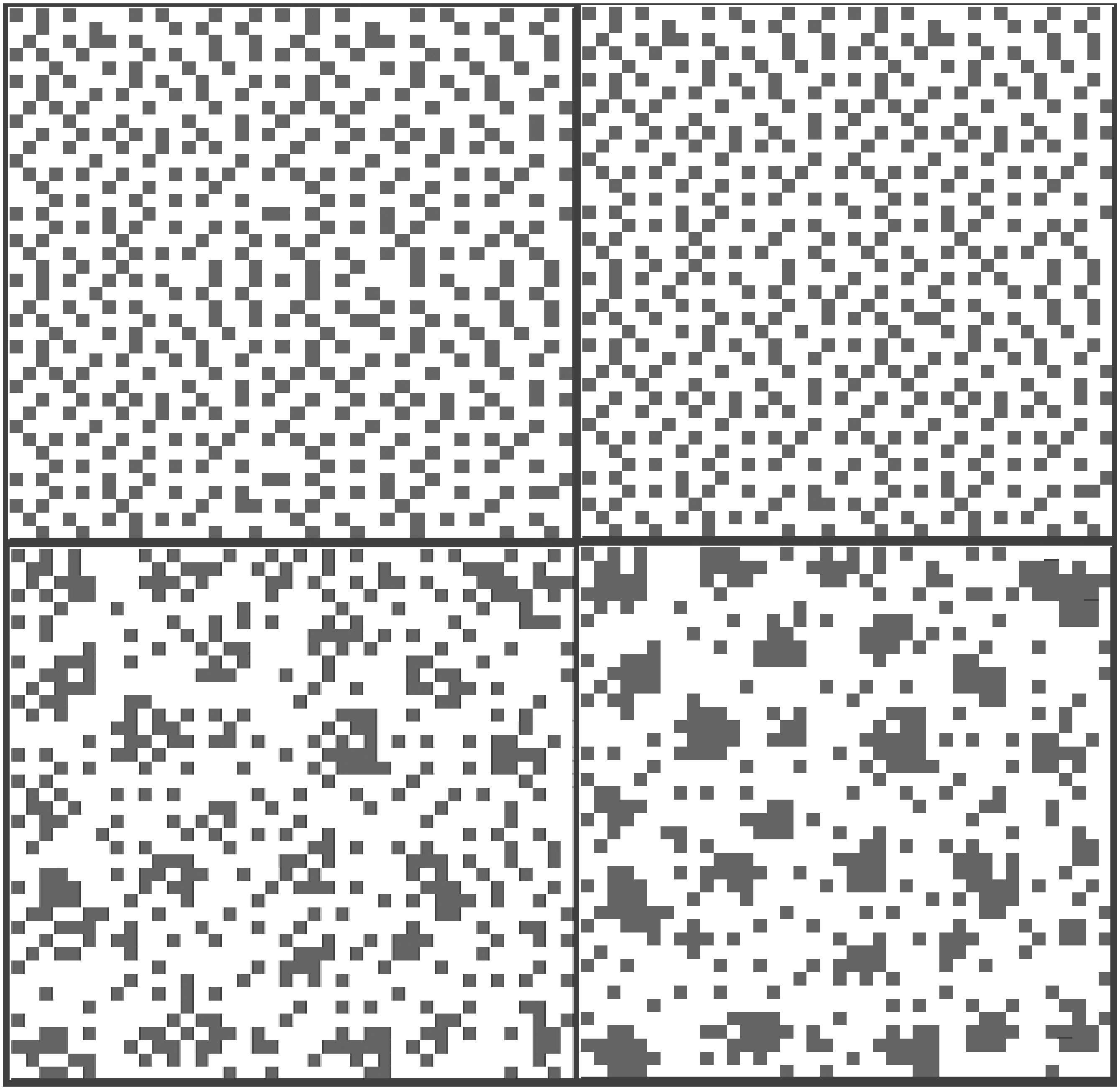


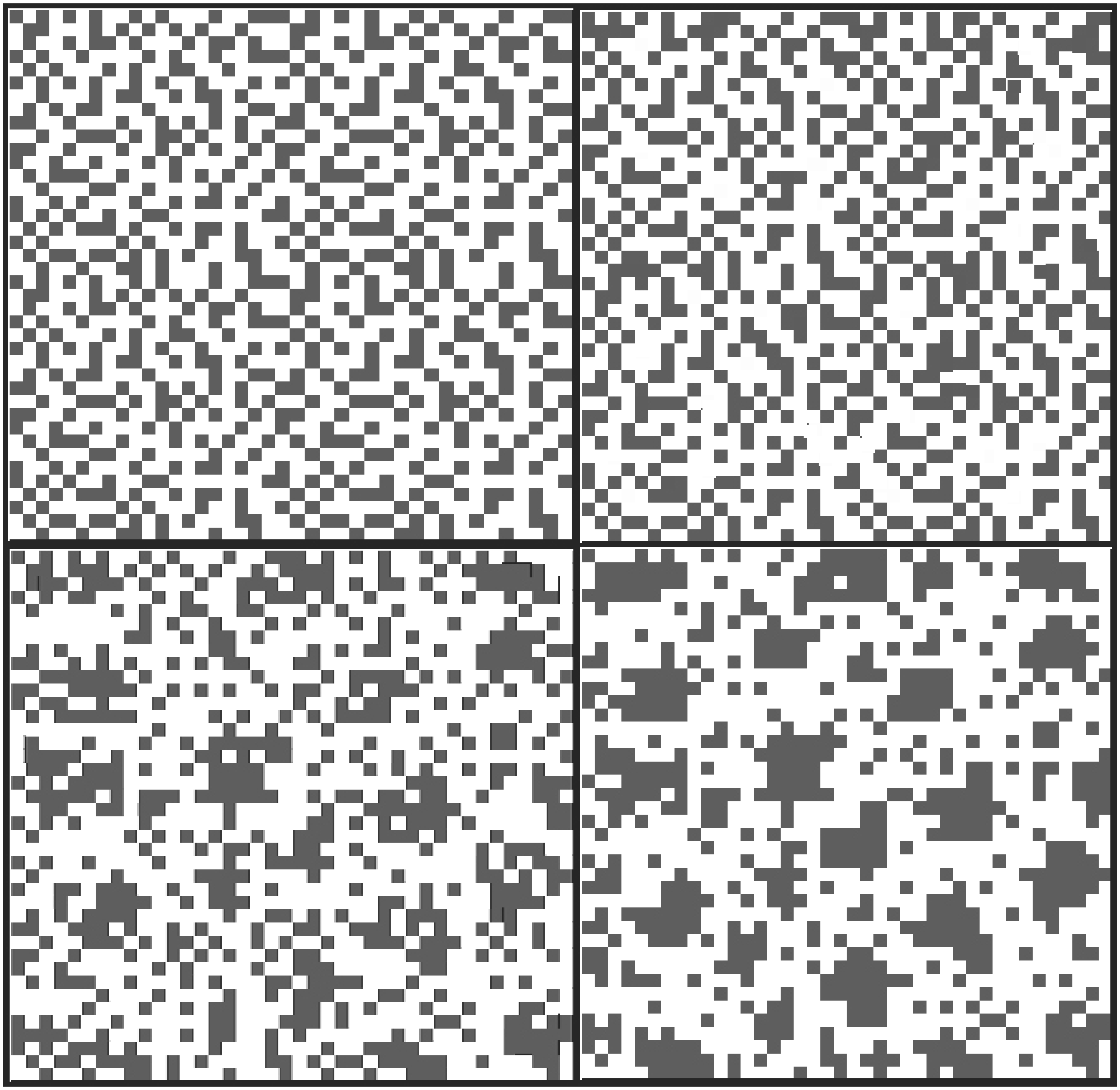
20%



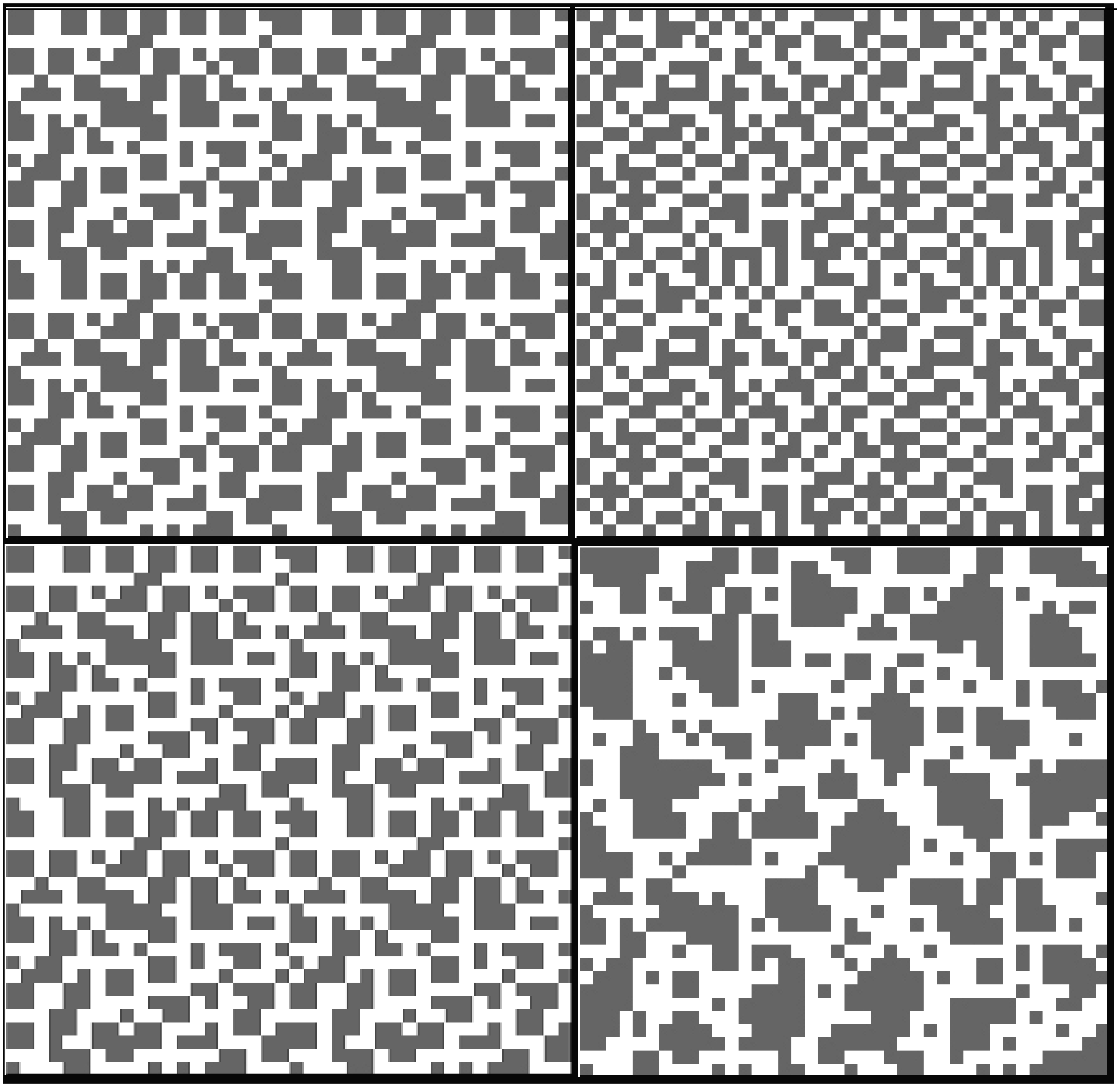
30%



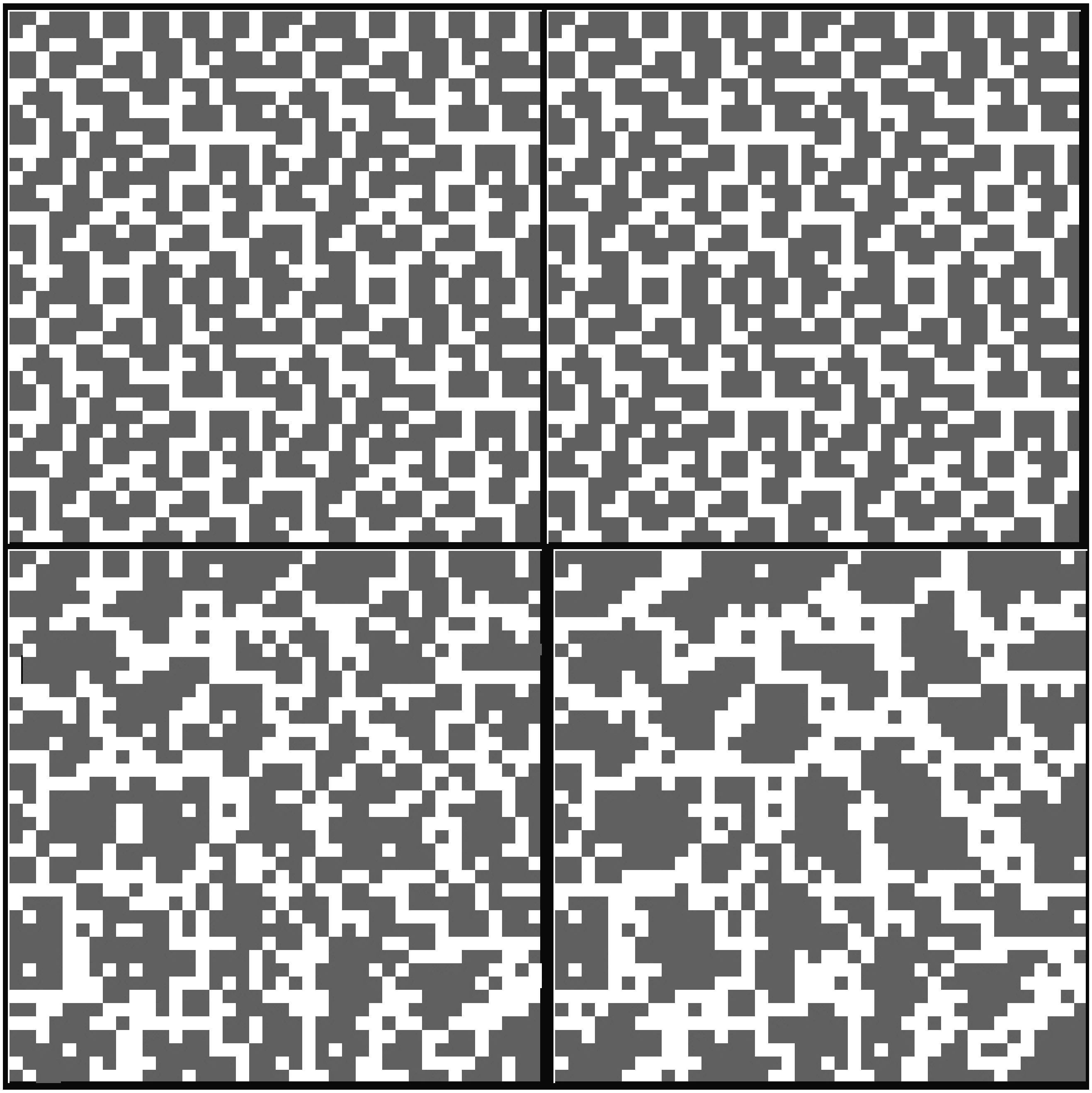
40%



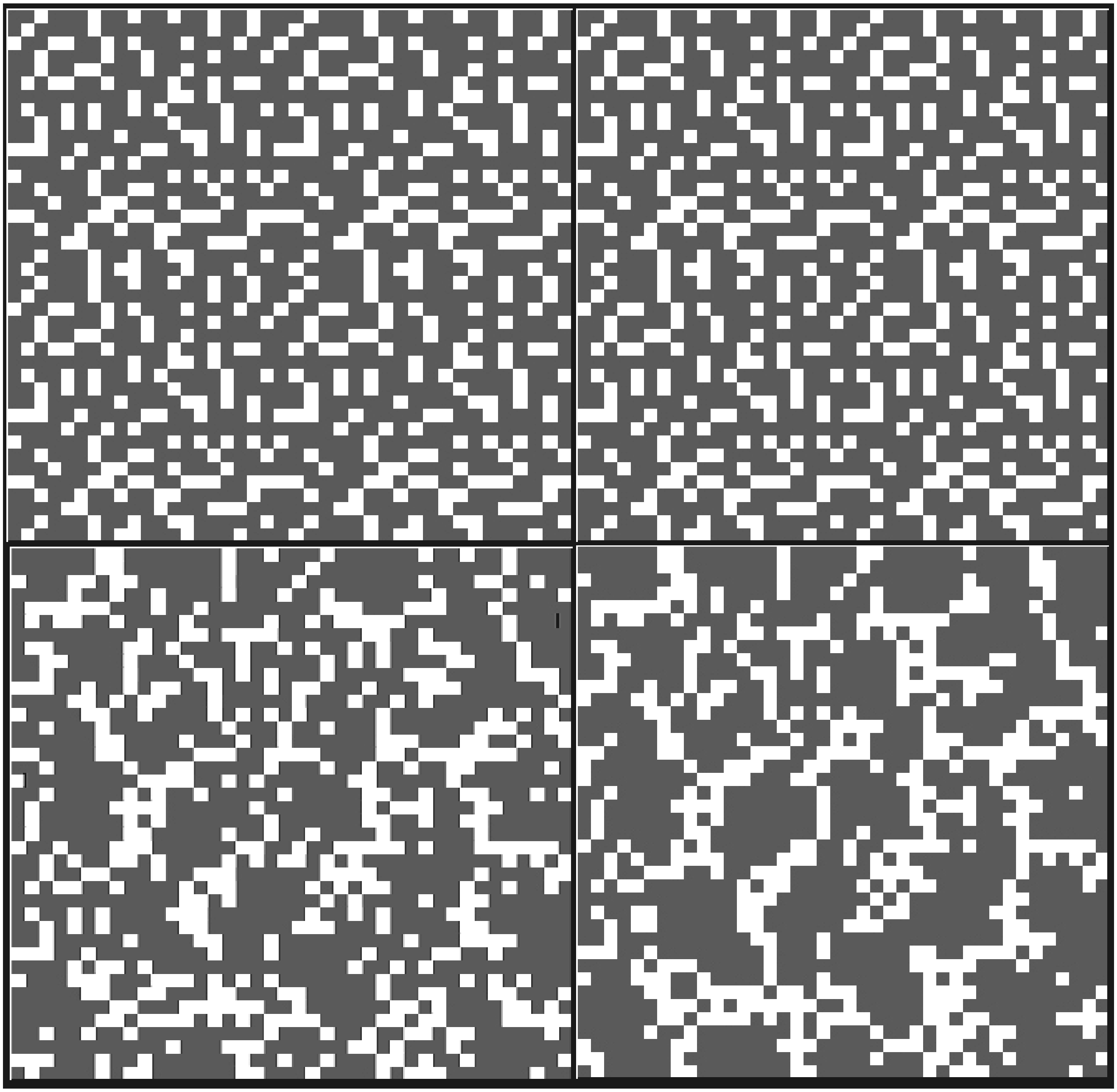
50%

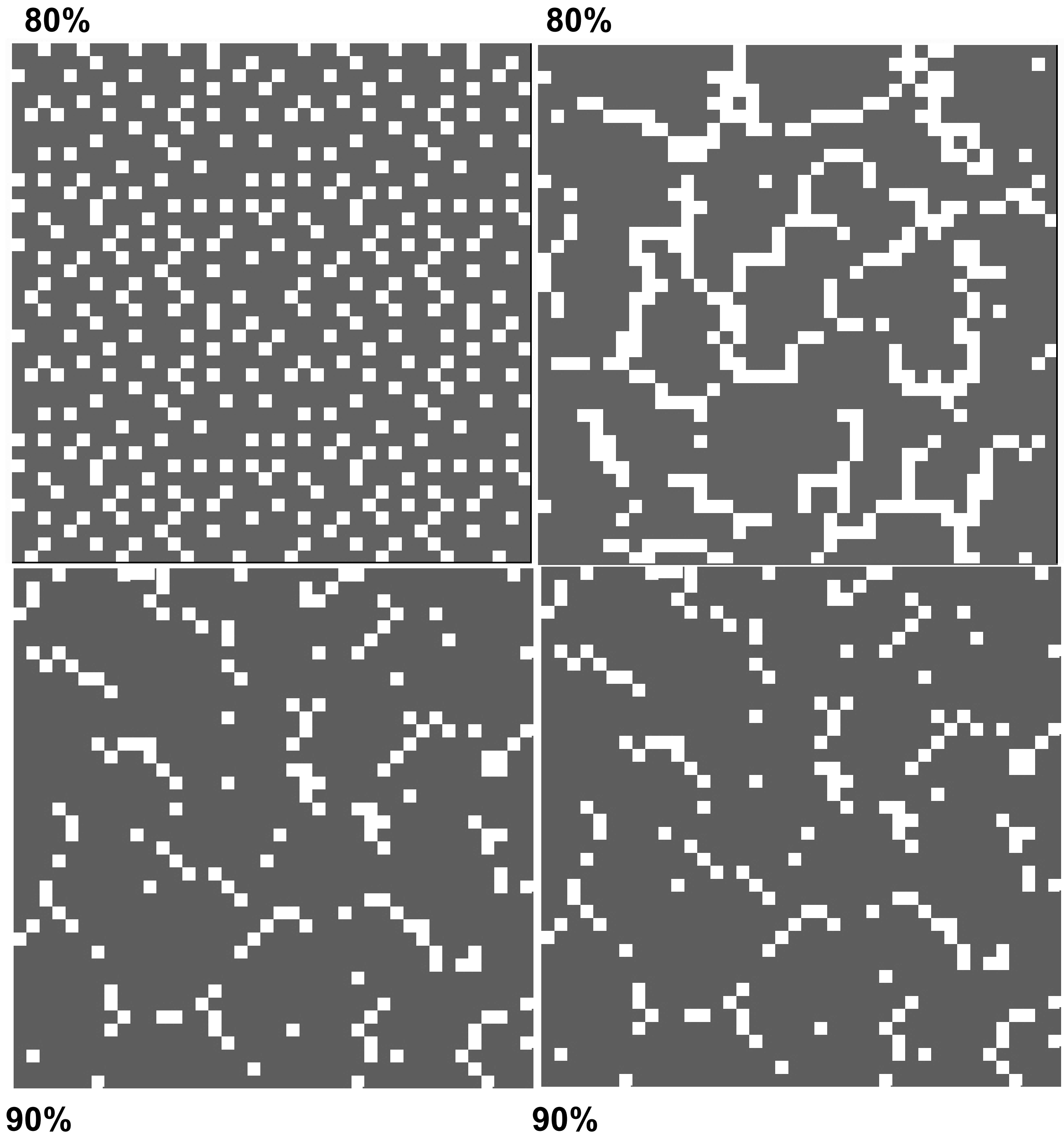


60%

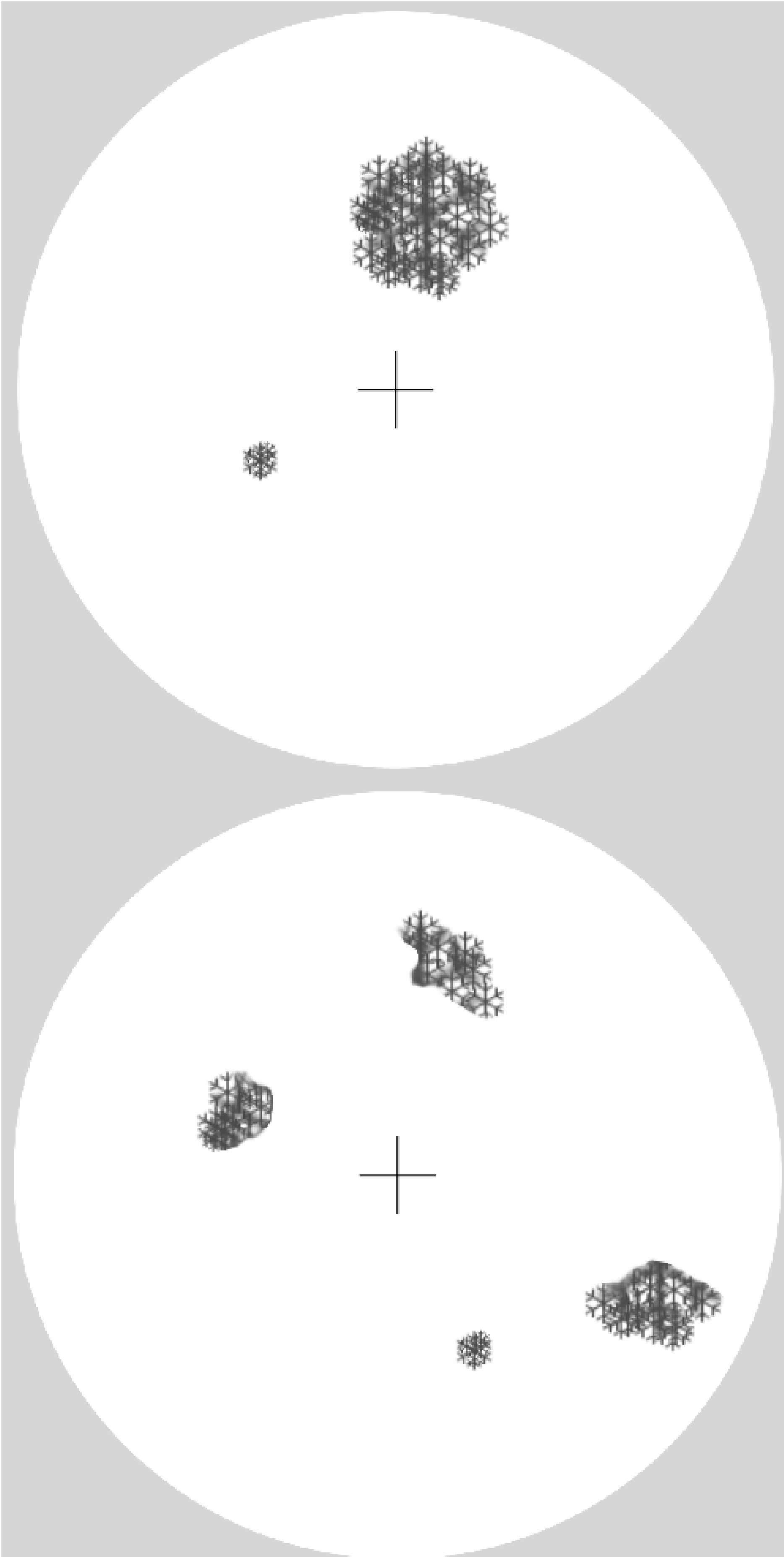


70%

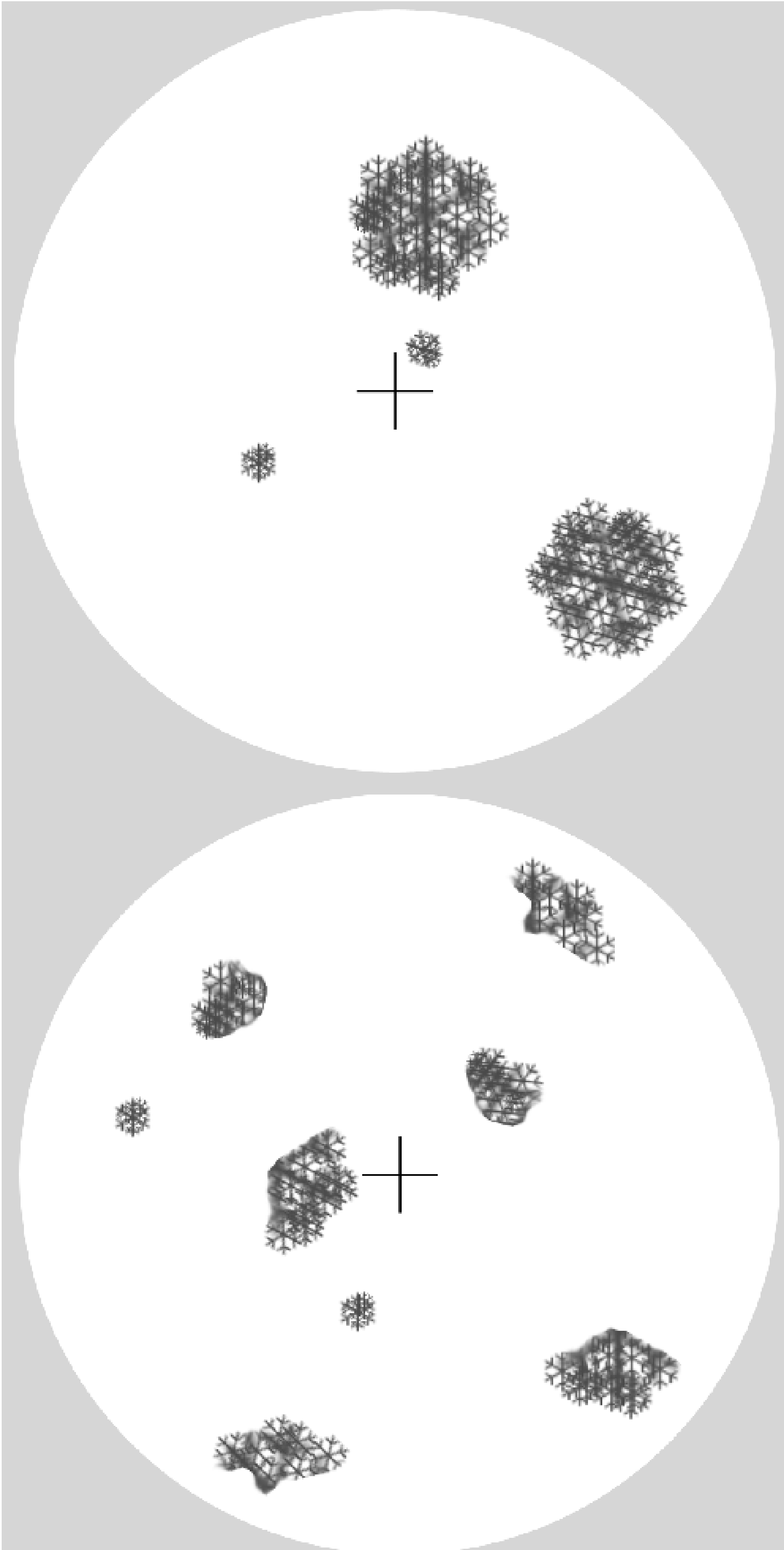



80%
80%
90%
90%

CLUMPS – 5%



CLUMPS 10%



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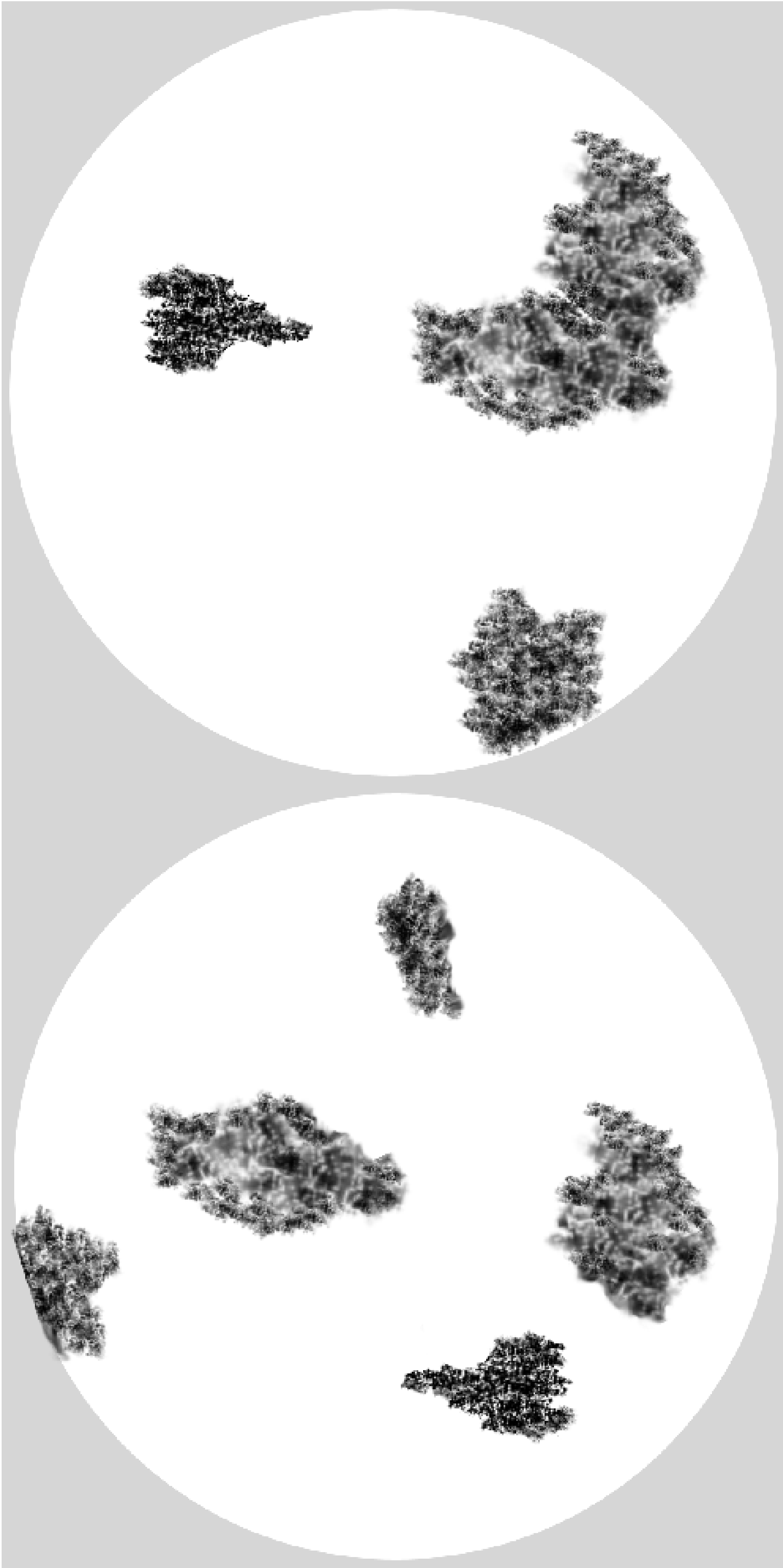

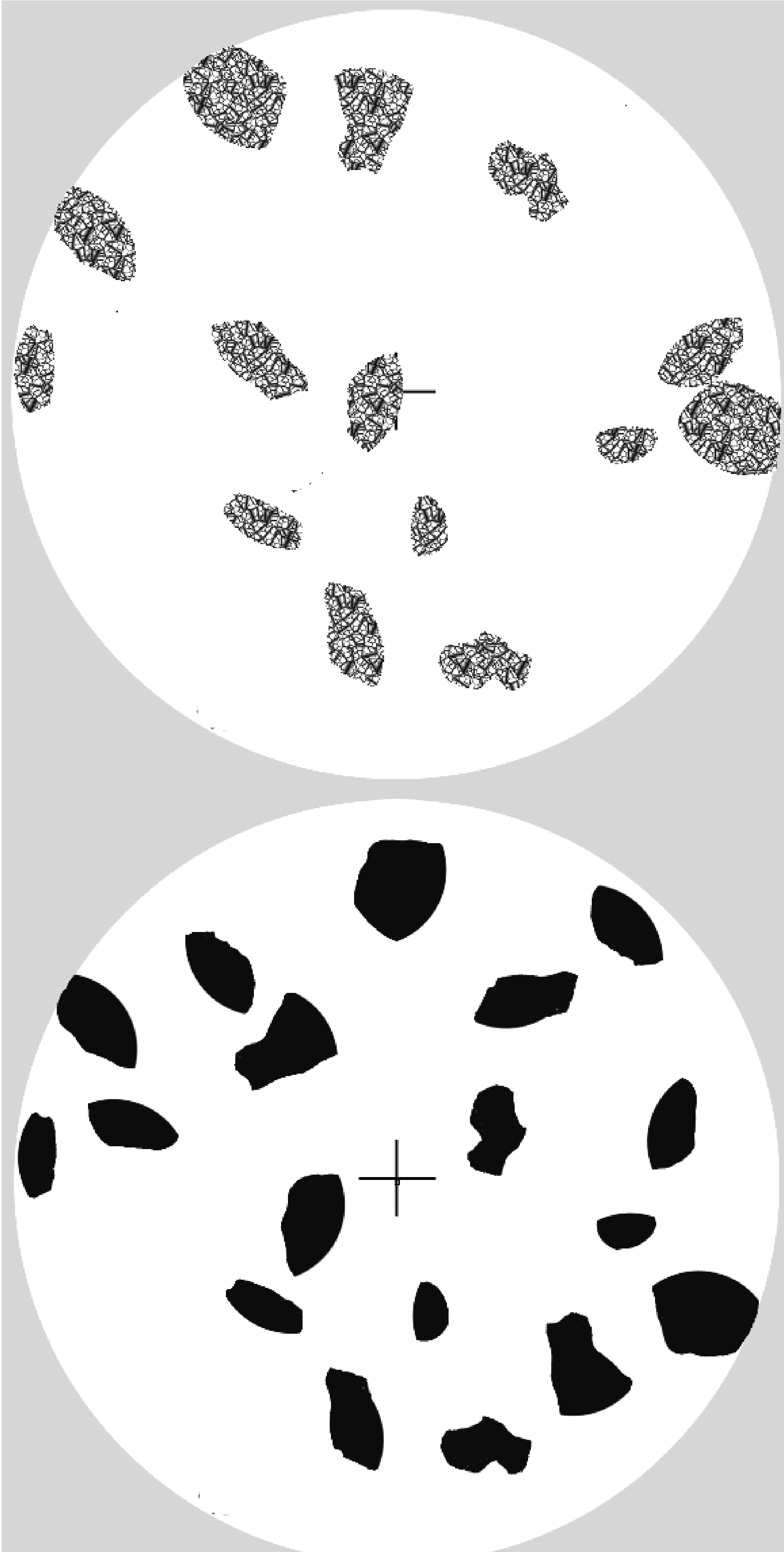

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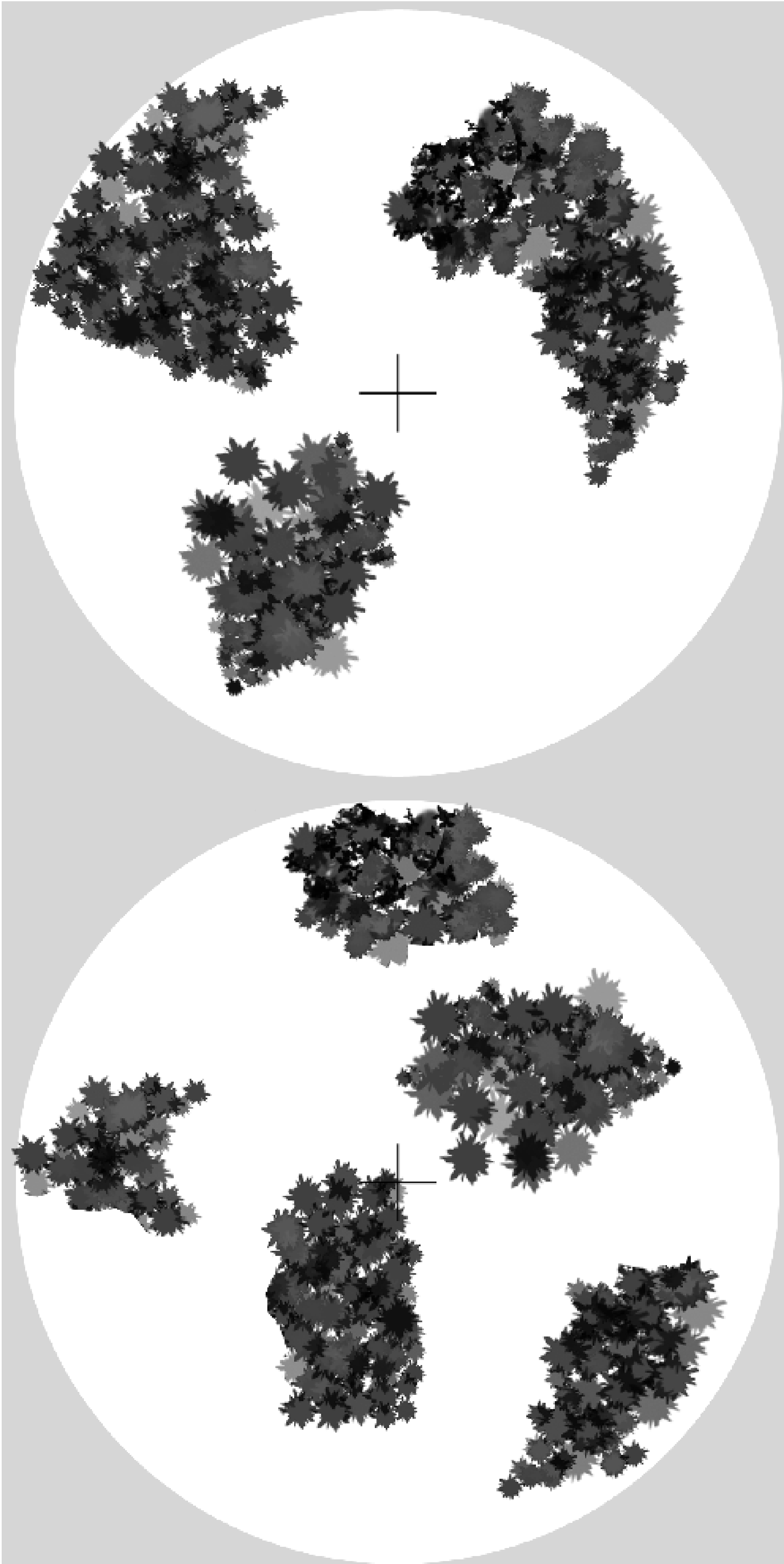

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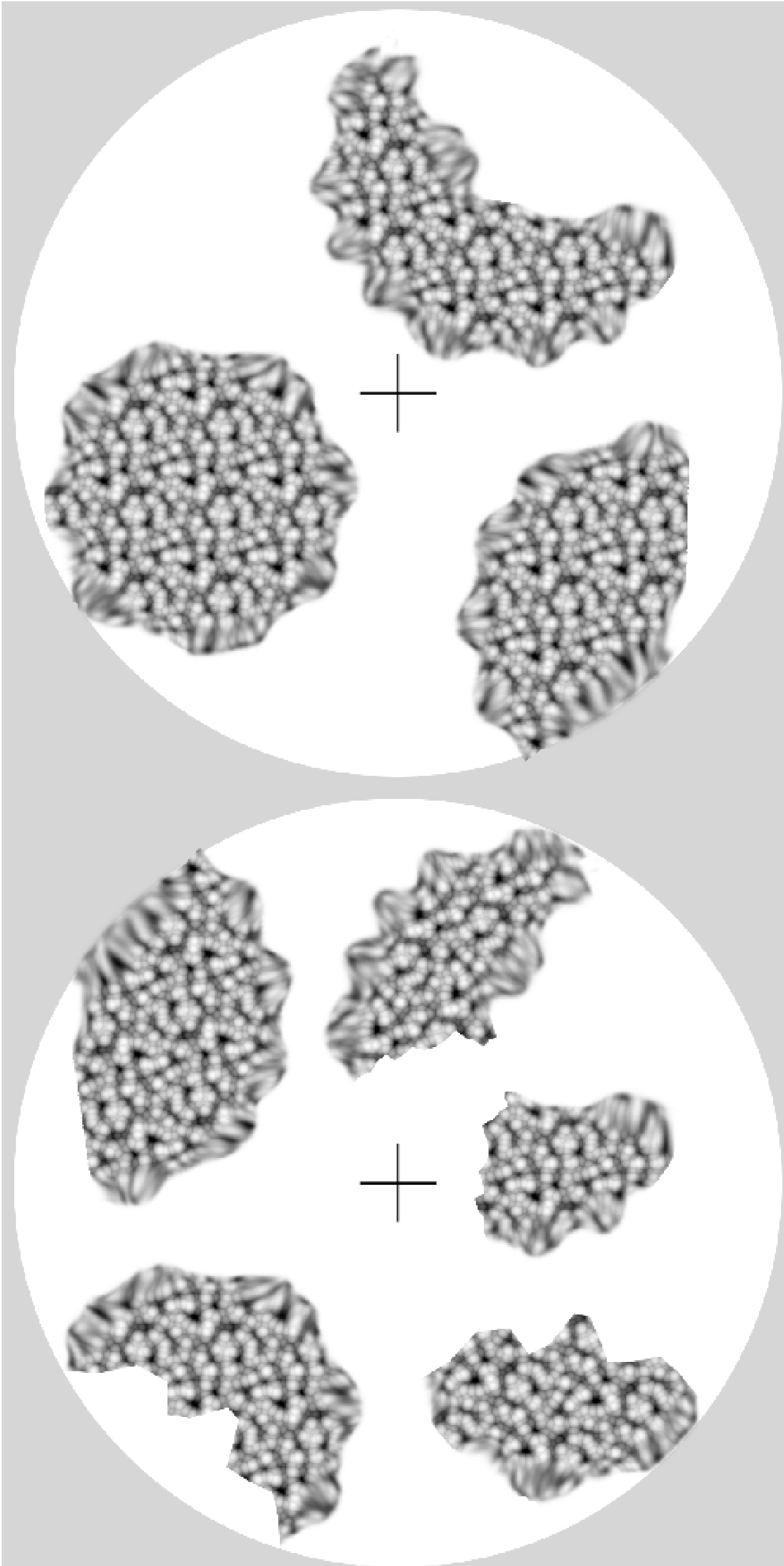
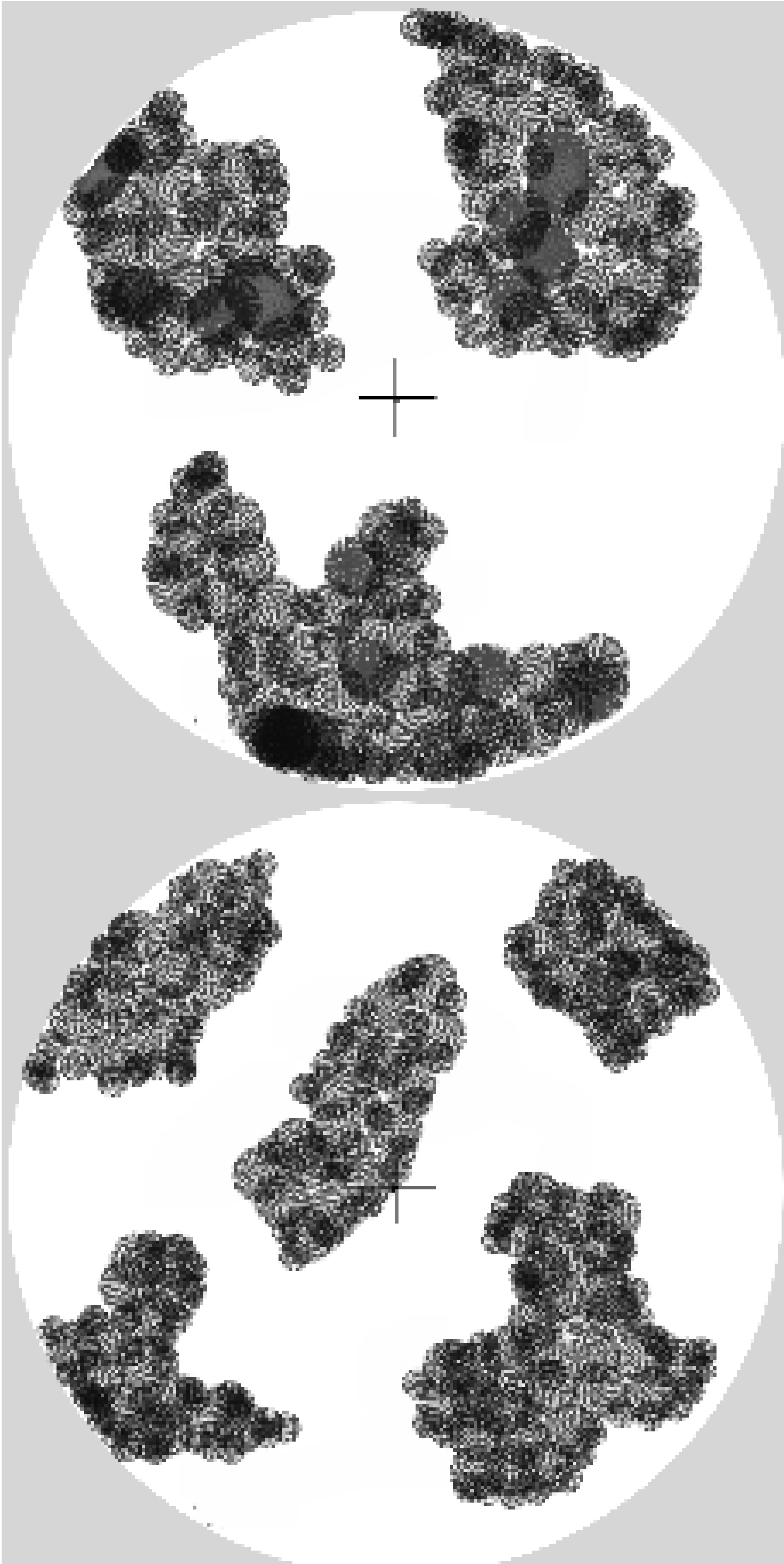
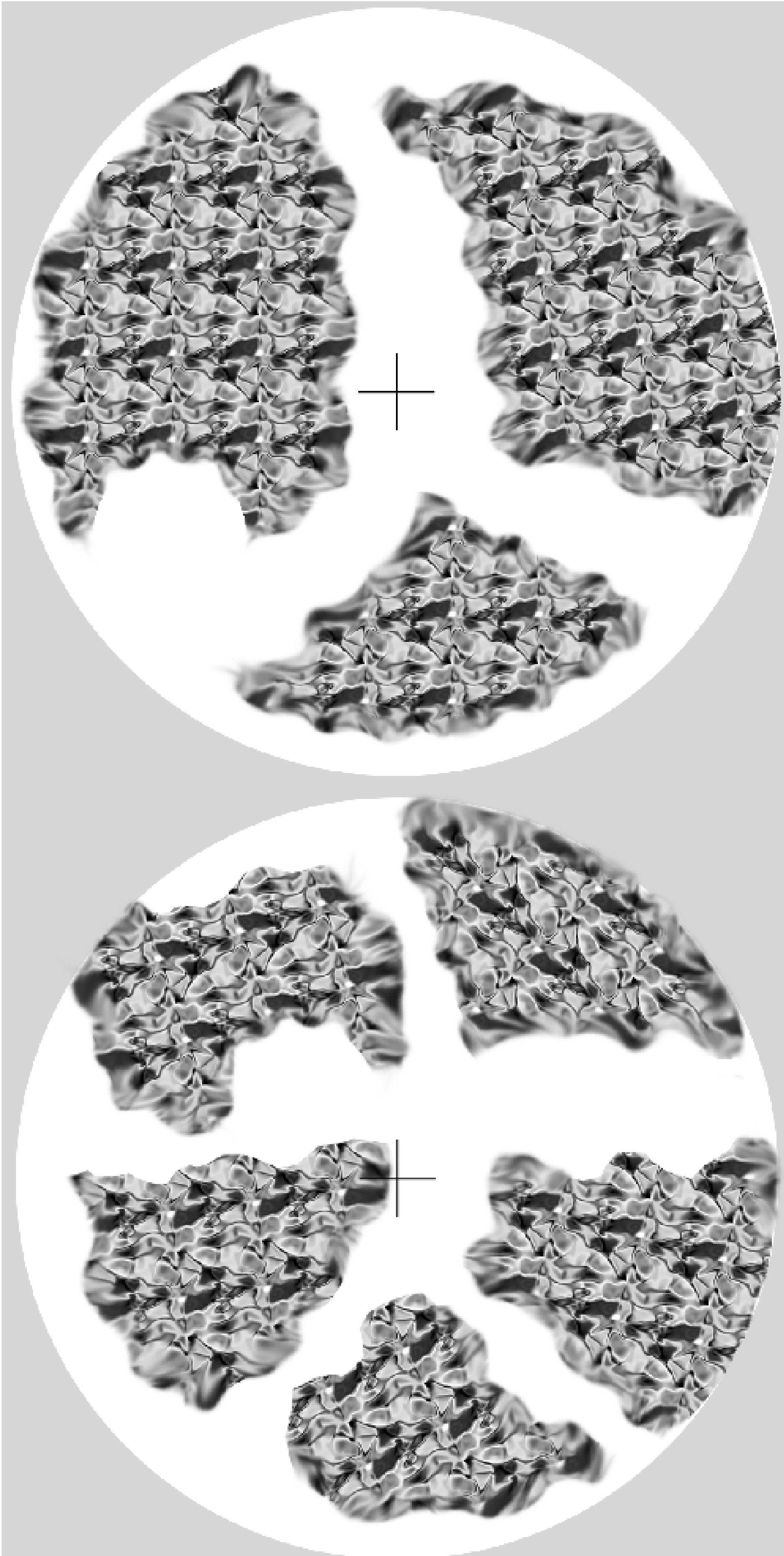
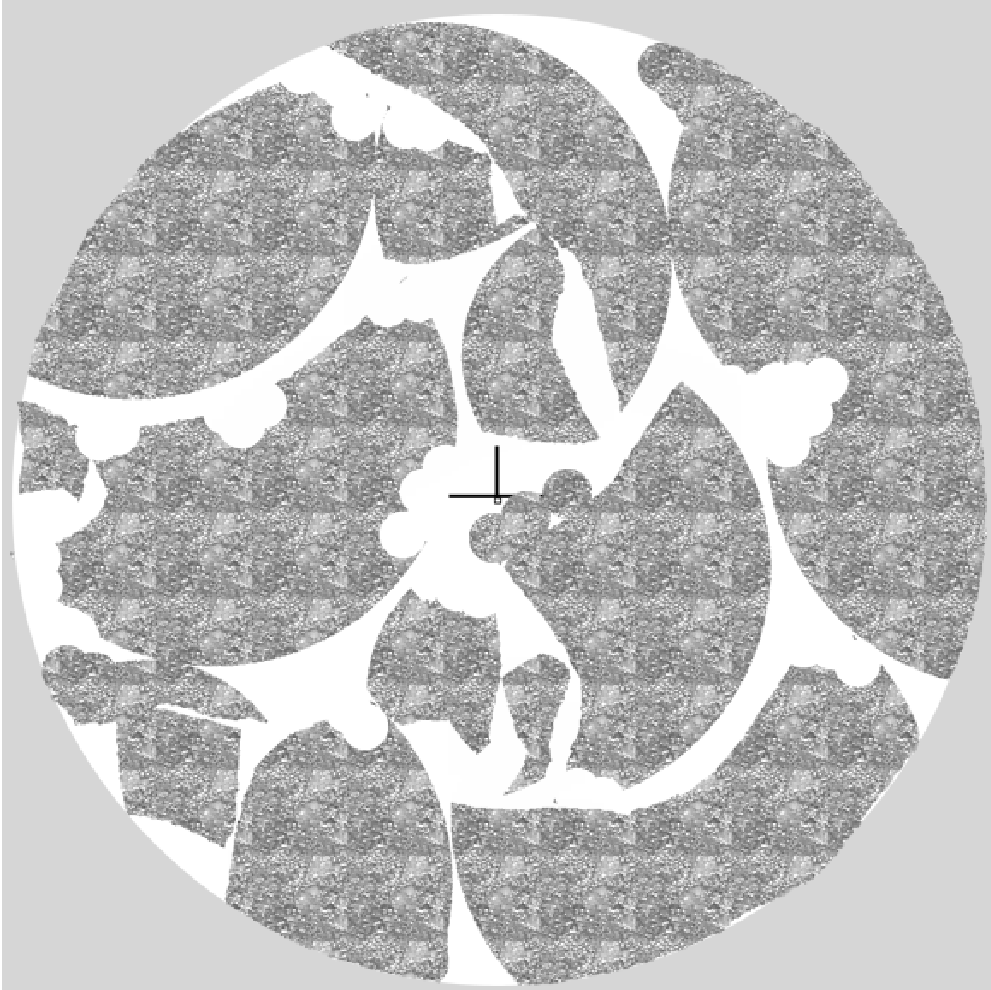


CLUMPS 50%

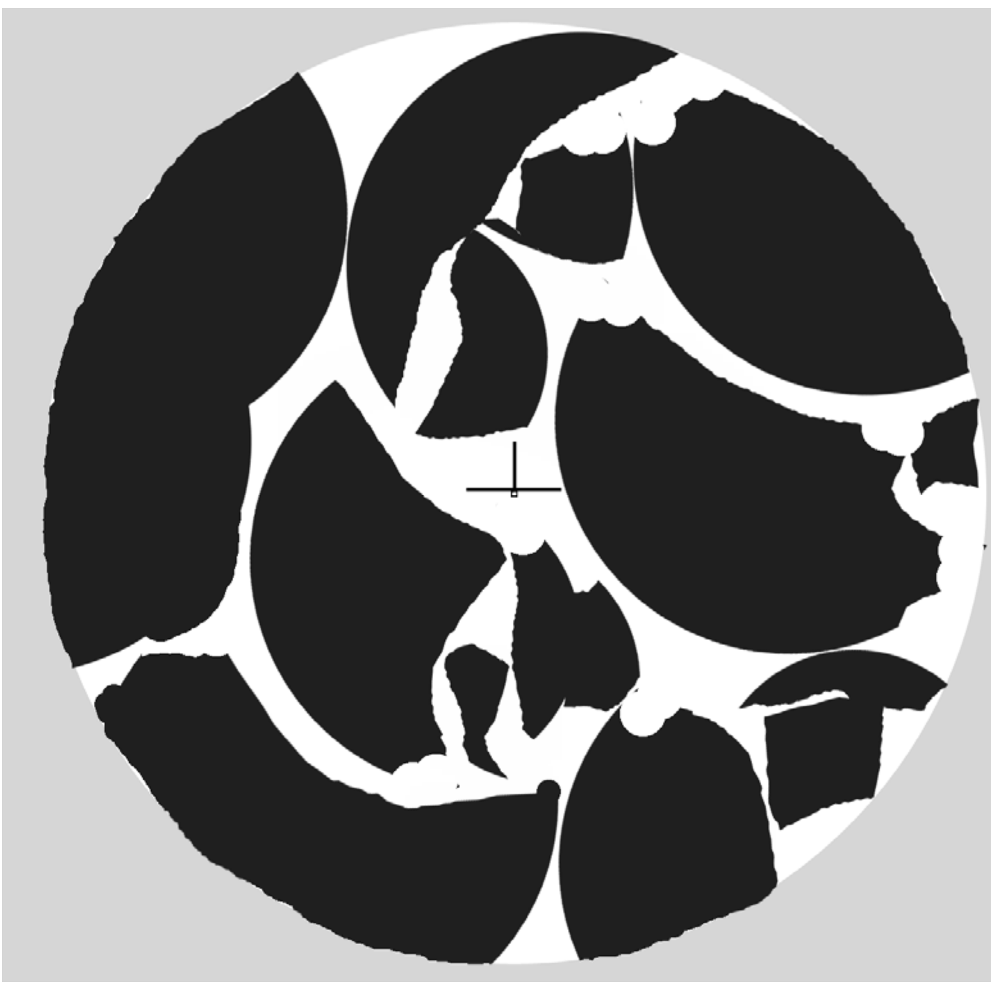


CLUMPS 60%



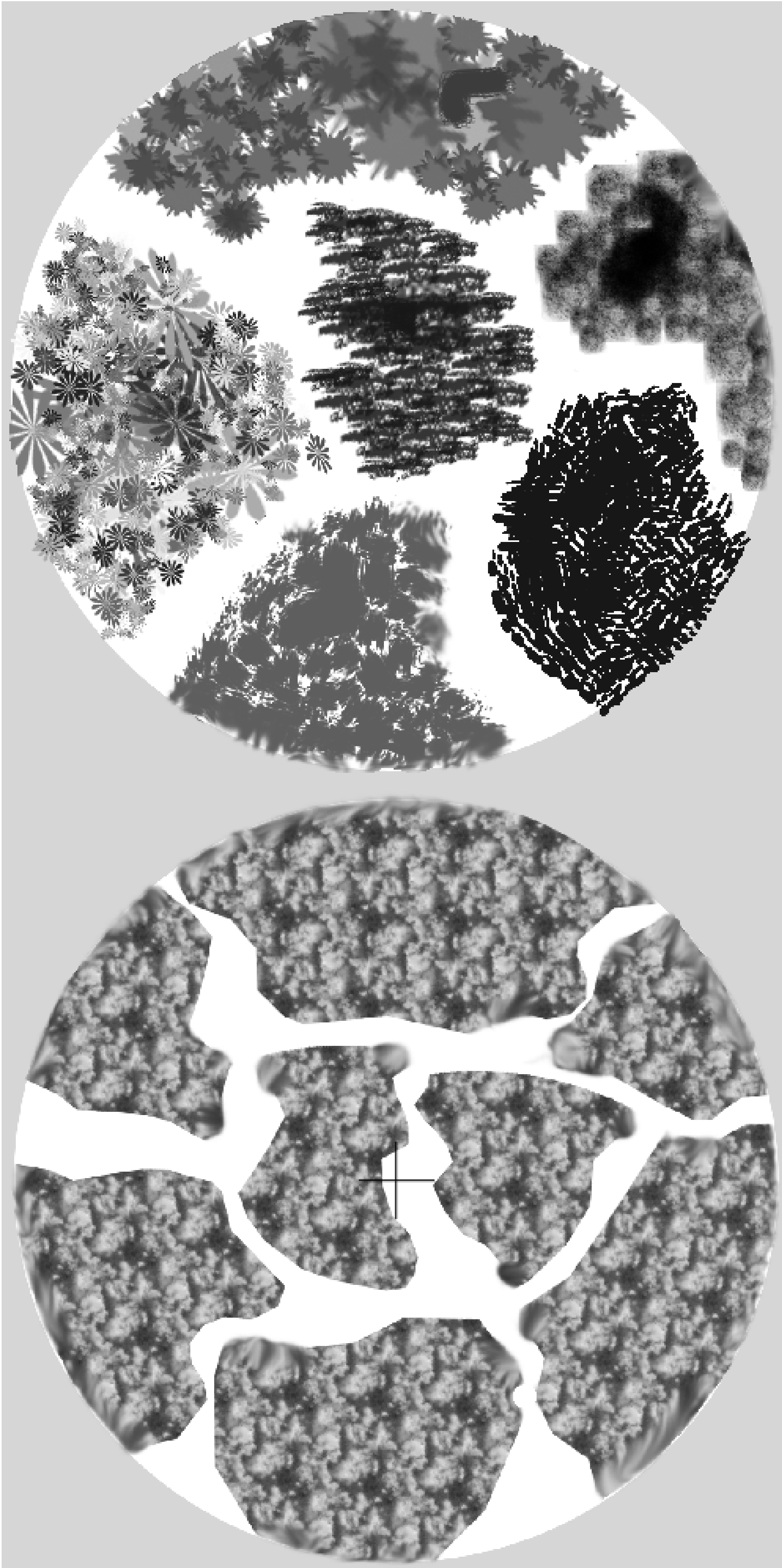


70%

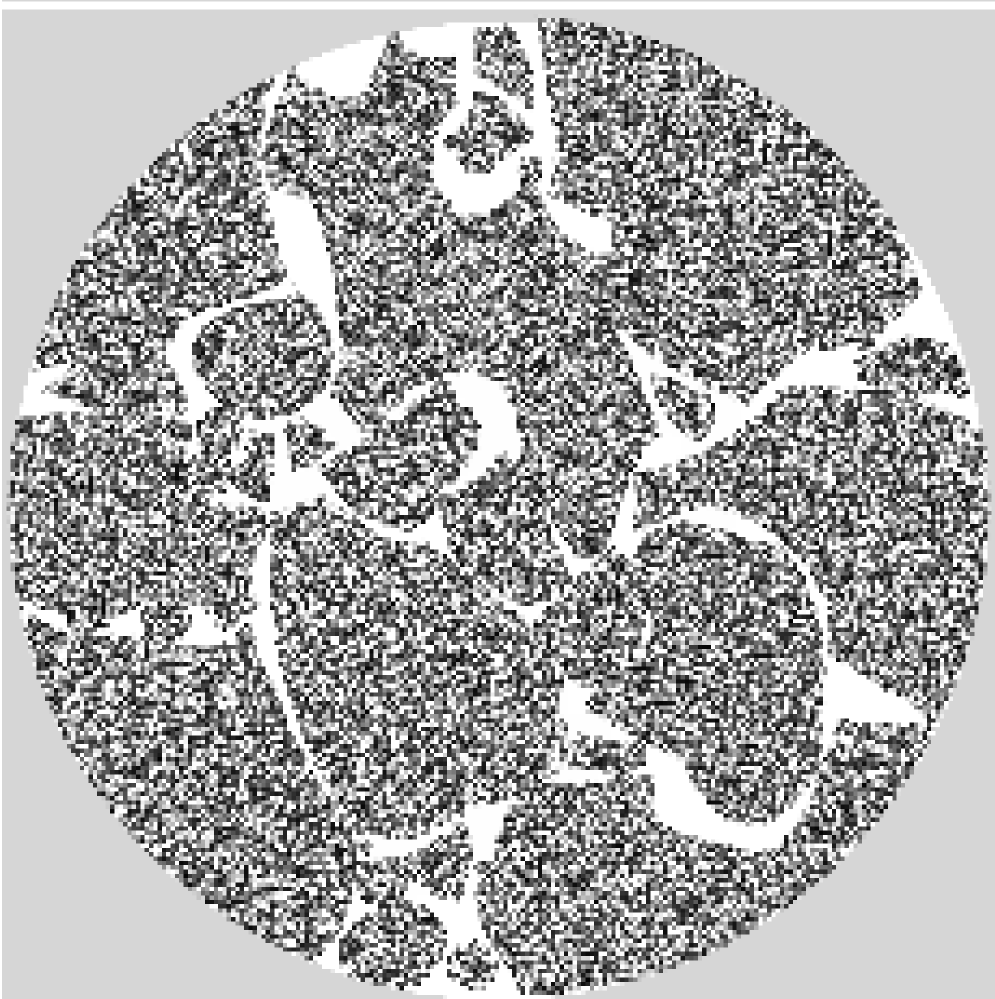


CLIMPS: 75%

CLUMPS 81%



84%



90%