Description of matrix transitions in EFISCEN

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1. Introduction

This document describes how area moves between matrix cells in the EFISCEN model. The examples are given for Utopia, which is an imaginary country with forest resources consisting of 1 region, 1 owner, 1 site-class and 1 tree species. The basic input data are shown in Table 1. Age classes are 20 years wide and the first includes bare forest land, i.e. forests without trees due to for example clear cut.

Table 1: Basic input data for Utopia.

Age class	Area (ha)	Growing stock (m^3 ha^{-1})	Net annual increment (m^3 ha^{-1} yr^{-1})
0-20	567560	14	1.63
21-40	348815	89	6.88
41-60	165344	158	7.33
61-80	219372	183	6.21
81-100	254784	200	5.32
101-120	142557	199	4.35
121-140	53705	180	3.34
141-160	17692	181	2.76
>160	7663	226	2.55

2. Initialisation of the age-volume matrices

Table 2 shows how the inventory data of section 1 is distributed over the age-volume matrix by the P-2009 tool. The numbers in the matrix are thousands of hectares of forest. The lower left cell is the bare-forest-land class. Mean volume in a volume class is the median of the volume class. For example, forests in the volume class with the upper limit of 220 m^3 ha^{-1} have a mean volume of 192.5 m^3 ha^{-1}. The used parameters are *cv* = 0.65, *r* = 0.50 and VCW_1 = 55. VCW_1 is the upper limit of the first volume class. Parameters *cv* and *r* describe how the area is distributed around the mean volume.

Table 2: Initial distribution of area over age and volume classes (1000 ha) and re-calculated average volume per age classes.

		Age class									
		0-20	21-40	41-60	61-80	81-100	101-120	121-140	141-160	>160	Total
Upper limit volume class	550	0	0	0.02	0.28	1.04	0.82	0.24	0.1	0.12	2.62
	495	0	0	0.24	1.38	2.83	1.75	0.57	0.2	0.13	7.1
	440	0	0	1.36	3.48	4.81	2.7	0.92	0.31	0.19	13.77
	385	0	0	3.2	5.28	7.96	4.65	1.4	0.48	0.44	23.41
	330	0	0	5.34	12.63	21.4	12.13	3.42	1.18	0.97	57.07
	275	0	0.19	15.98	33.17	47.05	25.5	7.65	2.53	1.66	133.73
	220	0	36	38.25	60.52	73.4	39.15	12.83	4.14	2.07	266.36
	165	0	72.46	56.92	67.76	74.87	41.31	14.99	4.81	2.03	335.15
	110	0	136.36	42.23	34.87	21.42	14.55	11.42	3.82	0.06	264.73
	55	288.94	103.8	1.79	0	0	0	0.26	0.11	0	394.9
	0	278.62	0	0	0	0	0	0	0	0	278.62
	Total	567.56	348.81	165.33	219.37	254.78	142.56	53.7	17.68	7.67	1777.46
	Average volume (m^3/ha)	14	89	158	182	200	199	180	181	228	112

3. Estimation of the growth functions

Table 3 shows the data on average volume and current annual increment from the inventory data (same as Table 1). For each age class, the 5-year increment percentage is calculated (column 4). These data points are used to estimate the coefficients a_0, a_1 and a_2 for the growth function (Table 4). This can be done, for example, using Microsoft Excel. The predicted increment (Table 3, column 5) is the increment calculated using the growth function.

Table 3: Basic inventory data (average volume and current annual increment) per age class, the calculated 5-year increment percentage and the predicted 5-year increment percentage using Equation 5 and the regression coefficients from Table 4.

Age years	Volume m^3ha^{-1}	Increment $m^3ha^{-1}yr^{-1}$	5-year increment %	Predicted increment %
0-20	14	1.63	58.21	58.24
21-40	89	6.88	38.65	38.04
41-60	158	7.33	23.20	24.23
61-80	183	6.21	16.97	17.31
81-100	200	5.32	13.30	13.20
101-120	199	4.35	10.93	10.50
121-140	180	3.34	9.28	8.58
141-160	181	2.76	7.62	7.15
>160	226	2.55	5.64	6.56

Table 4: Estimated coefficients for the growth function for Utopia.

Coefficients	
a_0	-2.61
a_1	1525.20
a_2	-9166.63

4. Use of the growth functions

Let us take a look at the age class 90-95 year. Using the average age of 92.5 years, we can calculate the five-year increment percentage:

$$I_{vf} = a_0 + \frac{a_1}{T} + \frac{a_1}{T^2} = -2.61 + \frac{1525.2}{92.5} + \frac{-9166.63}{92.5^2} = 12.81\%$$

The average volume from the input data is 200 m^3 ha^{-1}. We can now derive the value for Beta for each volume class and calculate the corrected increment. For example, the second volume class has an average volume of 82.5 m^3 ha^{-1}, so Beta is 0.4. The corrected increment is then:

$$I_{va} = I_{vf} * (\frac{V_m}{V_a})^{beta} = 12.81 * (\frac{200}{82.5})^{0.4} = 18.25\%$$

i.e. the increment percentage is greater due to low volume, but the absolute increment (m^3 ha^{-1}) is actually lower than in stands with larger volume. The absolute increment is:

$$18.25\% * 82.5 m^3 ha^{-1} = 15.05 m^3 ha^{-1}$$ (in 5 years)

Table 5 shows for all volume classes the calculated increment, before and after the correction, and in relative and absolute values.

Table 5: Increment calculations for age class 90-95 year

volume class	average volume	uncorrected increment			Beta	corrected increment		
	m^3 ha^{-1}	5 year %	m^3 ha^{-1} (5 years)	m^3 ha^{-1} yr^{-1}		5 year %	m^3 ha^{-1} (5 years)	m^3 ha^{-1} yr^{-1}
10	522.5	12.81	66.91	13.38	1	4.90	25.61	5.12
9	467.5	12.81	59.86	11.97	1	5.48	25.61	5.12
8	412.5	12.81	52.82	10.56	1	6.21	25.61	5.12
7	357.5	12.81	45.78	9.16	1	7.16	25.61	5.12
6	302.5	12.81	38.74	7.75	1	8.47	25.61	5.12
5	247.5	12.81	31.69	6.34	1	10.35	25.61	5.12
4	192.5	12.81	24.65	4.93	0.4	13.00	25.03	5.01
3	137.5	12.81	17.61	3.52	0.4	14.88	20.45	4.09
2	82.5	12.81	10.56	2.11	0.4	18.25	15.05	3.01
1	27.5	12.81	3.52	0.70	0.4	28.32	7.79	1.56

5. Transition fractions between cells

At t = 0 (at the beginning of simulations), there are 5355 ha (21420 ha / 4) in age class 90–95 and volume class 2 (55-110 m^3ha^{-1}). The age class width is 5 years, so in one time-step of 5 years, 100 % of the area will move to the next age class. The corrected increment percentage is 18.25%, and the absolute increment is 15.05 m^3 ha^{-1} in 5 years (see A.4). The difference with the next volume class is 55 m^3 ha^{-1}. The fraction of area that needs to be transferred to the next volume class is then 15.05 / 55 = 0.2736. Hence, 0.2736 * 5355 = 1465 ha will be transferred to a higher volume class and 3890 ha will remain in the same volume class (Figure 1). At t=1, we find that the average age of the forest is 97.5 year and the average volume 97.55 m^3 ha^{-1}.

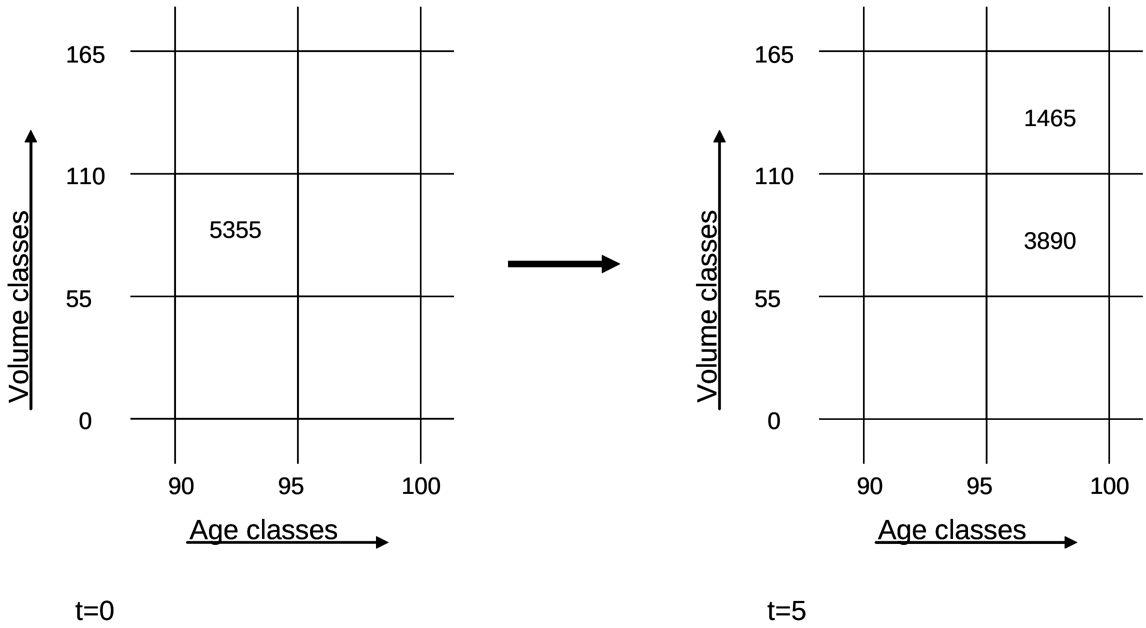

Figure 1: Transition of area through the matrix (area in ha) in case no thinning is applied.

6. Thinning

If we assume that in the previous example no area is having the recently thinned status, all of the area can be thinned. The difference in average volume between the first and second volume class, 82.5-27.5 = 55 m^3ha^{-1}, is the maximum that can be thinned per ha. So the total maximum available thinning amount is 55 * 5355 = 294525 m^3. If the required volume of thinning is 175000 m^3 during the five-year simulation step, 59.4% of the available area (175000 / 294525) need to be thinned. So 0.594 * 5355 = 3181 ha will be moved one volume class down. The resulting situation can be seen in Figure 2. Now these areas will grow normally according to the growth functions. The transition fractions are shown in the left part in Figure 3, and the resulting distribution of area in the right part. The average volume after one time-step will then be 60.56 m^3 ha^{-1} and 175000 m^3 has been thinned (6.54 m^3 ha^{-1} yr^{-1}).

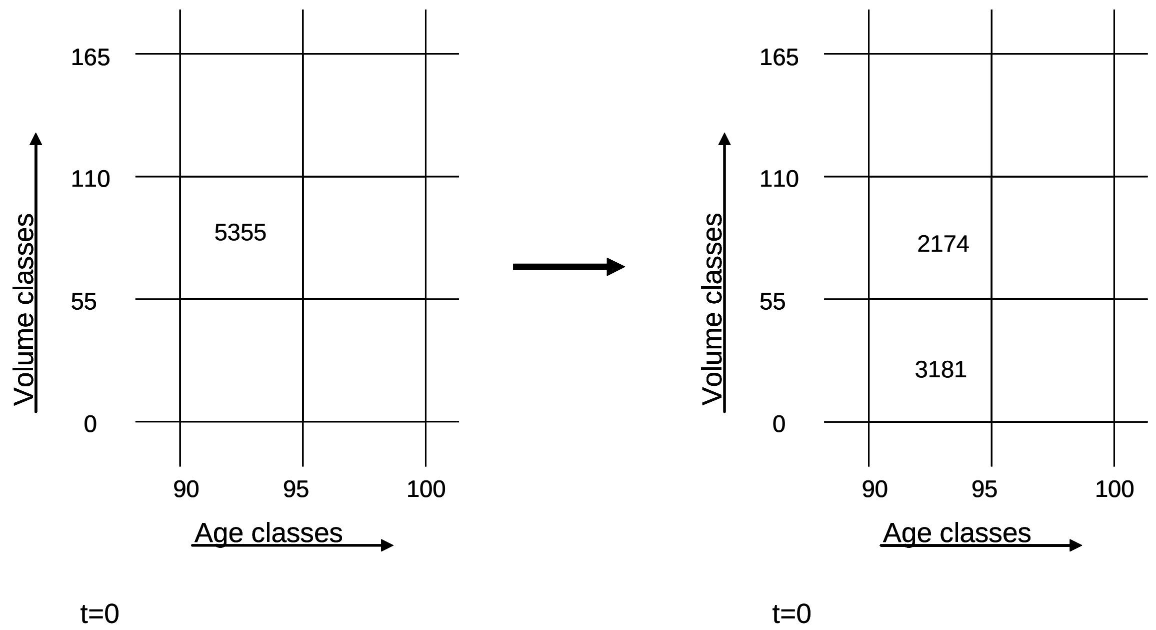

Figure 2: Area distribution of the matrix (area in ha) in case of a thinning, but before growth.

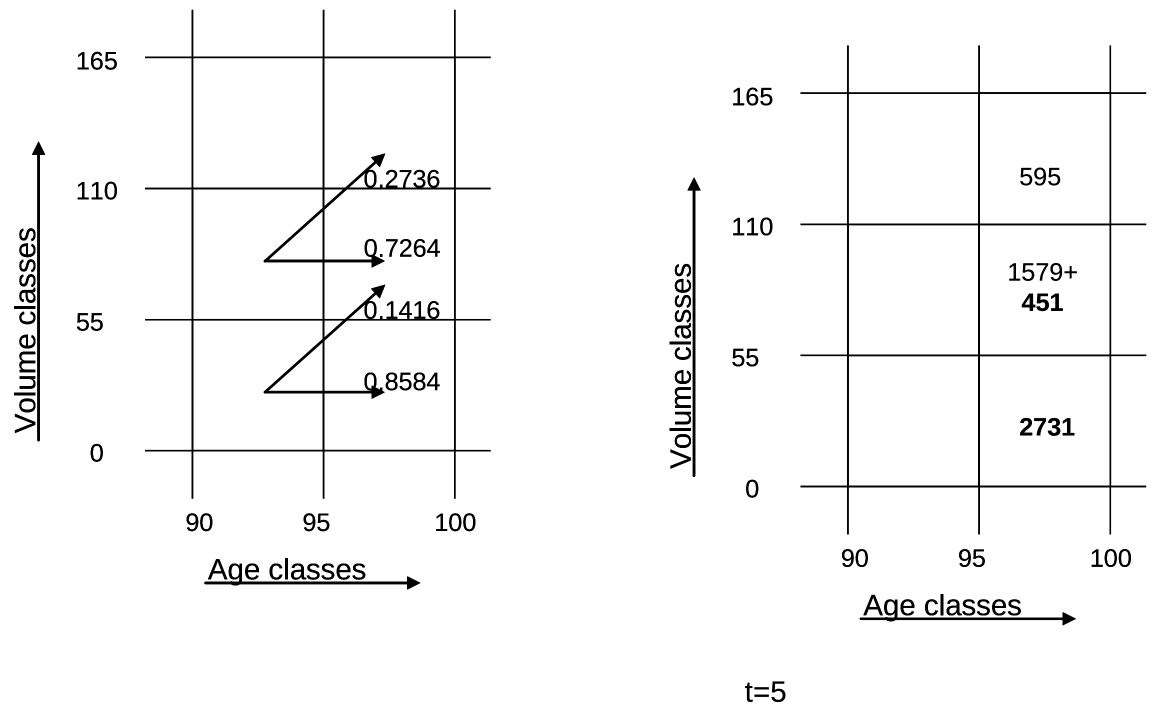

Figure 3: Transition fractions for part of the matrix and situation after thinning and growth. In bold the recently thinned area is shown.

7. Increment of thinned forests

The next time step 595 + 1579 = 2174 ha is available for thinnings (Figure 3), equal to 119580 m^3. However, we assume no thinnings the second time step. Both thinned and not thinned area will grow according to the normal transitions (Figure 4, transition calculations not shown). However, part of the area is waiting for a growth boost. Figure 5 shows the area that receives the growth boost in *italics*, assuming a growth boost parameter of 0.4. The average volume then equals 84.9 $m^3\ ha^{-1}$, while the increment has been 4.87 $m^3\ ha^{-1}\ yr^{-1}$.

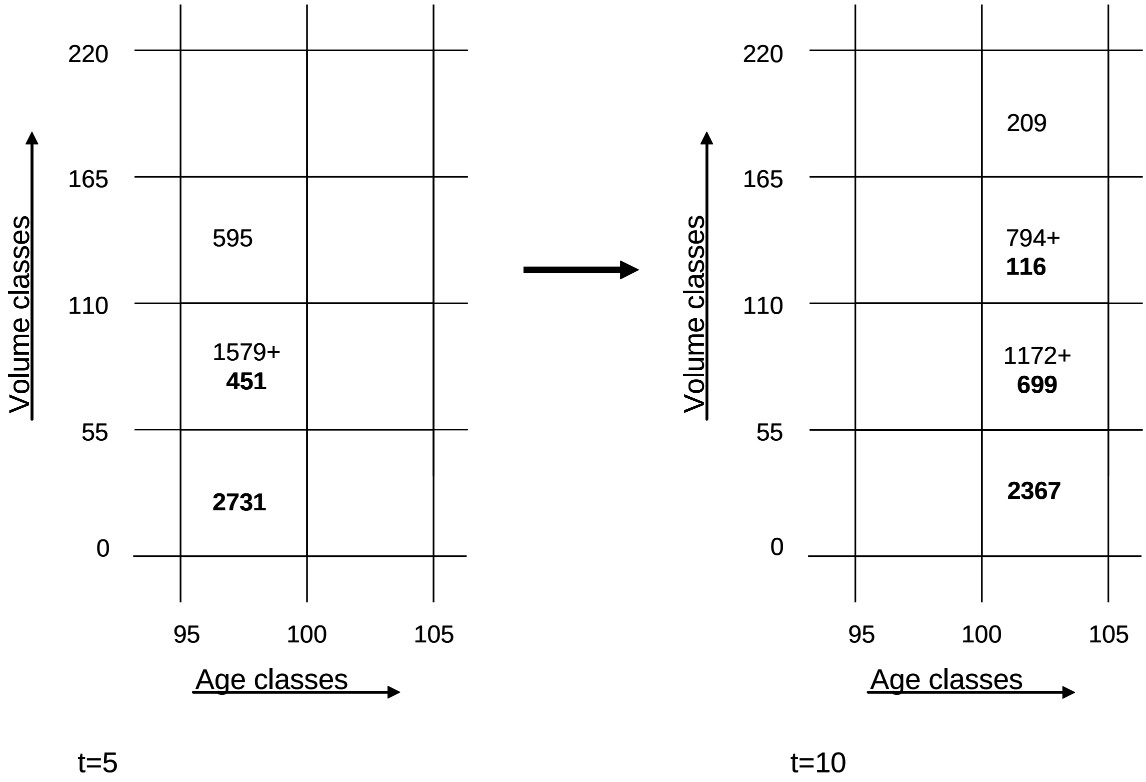

Figure 4: Area distribution after the second time step before the growth boost has been applied. In bold the recently thinned area is shown.

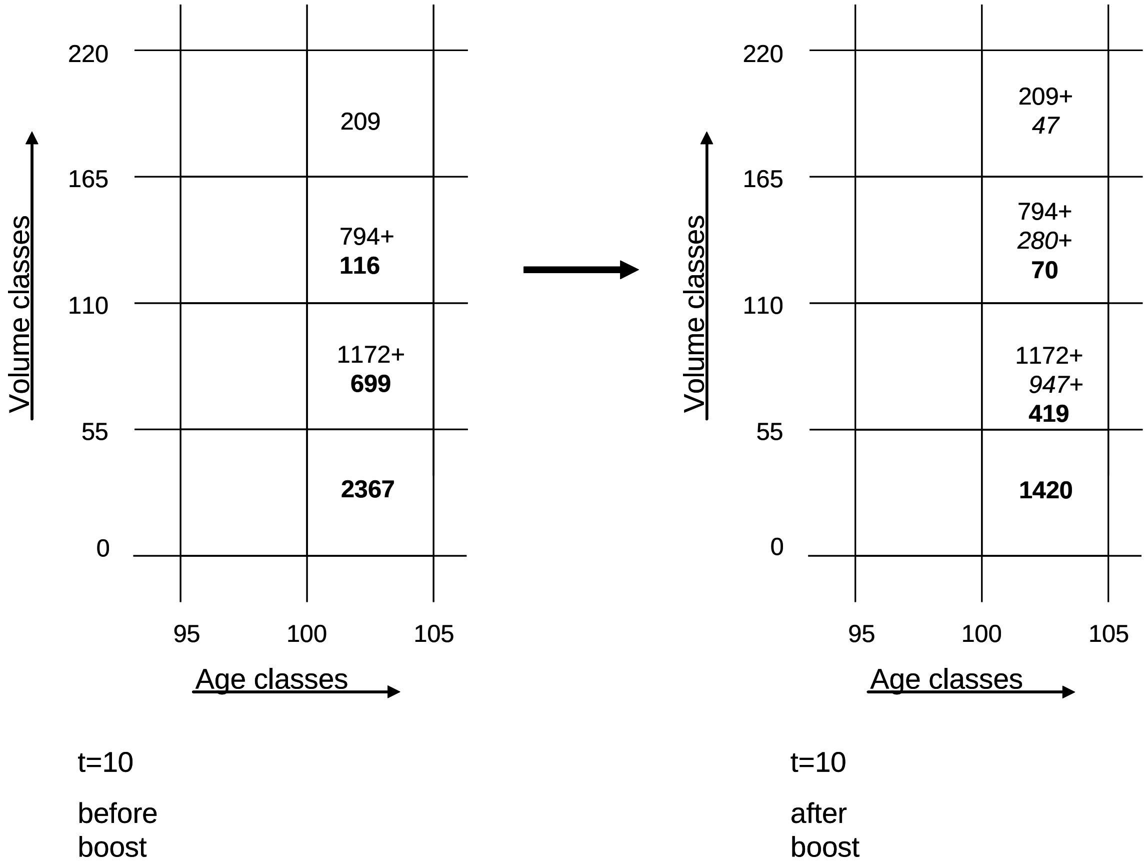

Figure 5: Area distribution after the second time step before and after the growth boost has been applied. In bold the recently thinned (i.e. waiting for growth boost) area is shown, in italics the area that has received the growth boost. This area will be available for thinnings the third time step.

8. Final felling

Alternatively, we can decide to do a final felling on the area shown in Figure 1. The final felling volume is then 5355 * 82.5 = 441788 m^3. All area will be moved to the bare forest land class, assuming no species change (Figure 6). With a young forest coefficient of 0.6, 60% of this area will move to the first age and volume class (Figure 7). At the end of the first time step, the average volume is 16.5 m^3 ha^{-1}, giving an average increment of 3.3 m^3 ha^{-1} yr^{-1}.

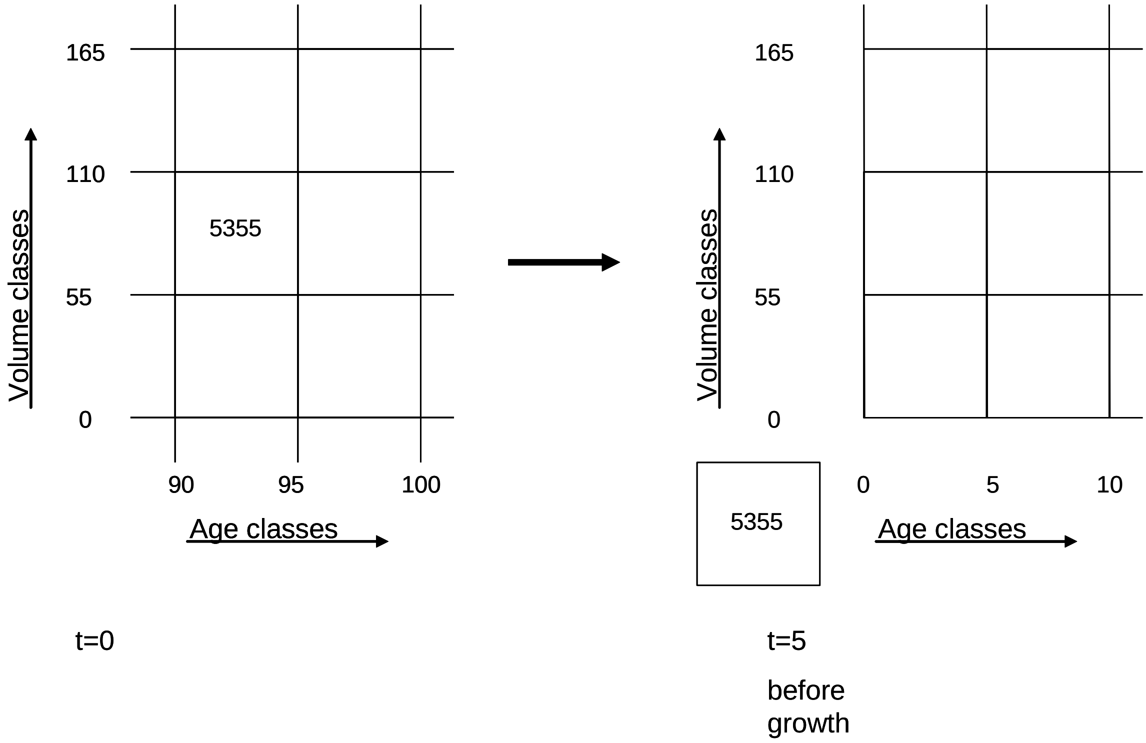

Figure 6: Area distribution after final felling, but before growth.

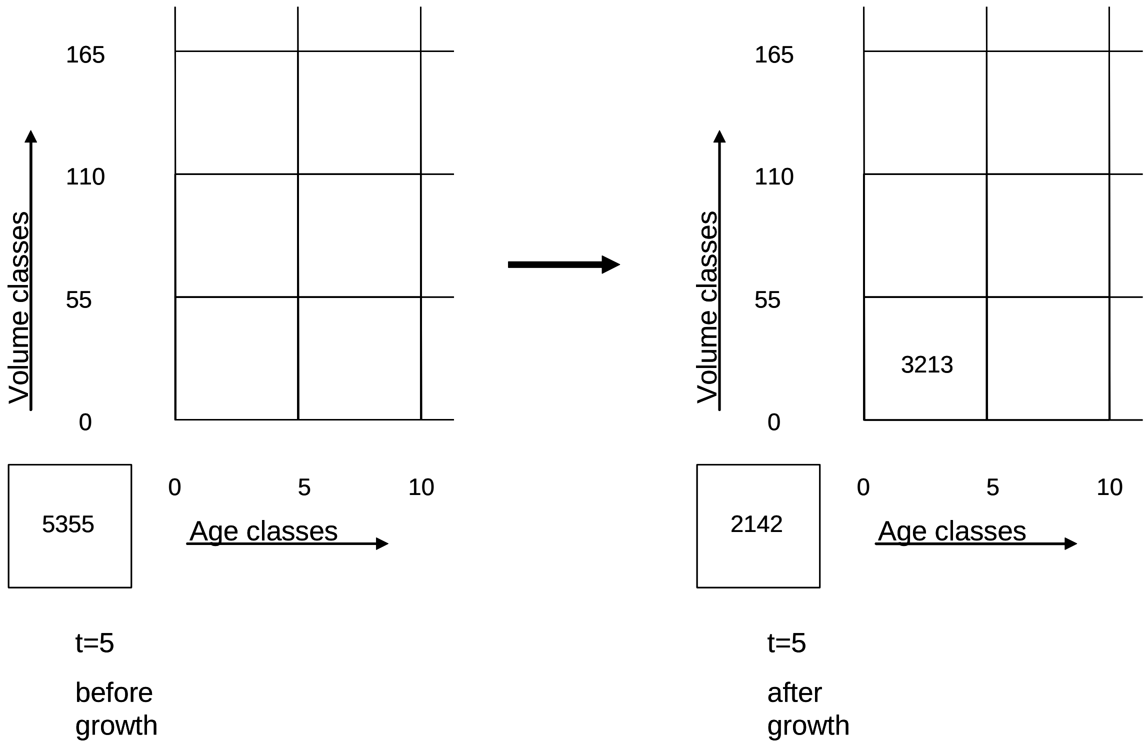

Figure 7: Area distribution at the end of the first time step.