

Supplementary Online File 1:  
A comparison of COVID-19 outbreaks across US Combined  
Statistical Areas using new methods for estimating  $R_0$  and social  
distancing behaviour

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## 1 Introduction

In this supplementary online file we report the two criteria for the choice of CSAs of interest (Section 2) and for day 0 of the epidemic outbreak (Section 3). We then present the final choice of CSAs (Section 4) and some considerations on the calculation of  $R_0$  (Section 5). We describe the choice of parameters for the NMB-DASA web app (Section 6) followed by the clustering procedure to extract weaker/stronger social distancing CSA responses and some additional clustering analysis (Section 7).

## 2 Criterion: choice of CSAs

As explained in the paper, we ranked the CSA by considering their total population, the number of cases and the number of deaths for each CSA, extracting data related to the COVID-19 epidemic from January 21, 2020 (which is the date of first case in the US) until September 5, 2020 (data downloaded from <https://usafacts.org/>). In particular, we ranked every CSA by population, by number of cases per 1000 people and by number of deaths per cases. We sum these 3 rankings and used the total rank to choose the CSAs of interest. By looking at this total ranking values, we chose the first 32 CSAs (by lowest ranking), given a gap in the ranking between these first CSAs and the following ones (140 CSAs), as shown in Figure 1 (total rank in the last column).

| CSA Code | CSA Name                                       | Population | Cases  | Deaths | Cases per 1,000 people | Deaths per cases (%) | Rank Population | Rank Cases | Rank Deaths | Total rank |
|----------|--|------------|--------|--------|------------------------|----------------------|-----------------|------------|-------------|------------|
| 400      | New York-Newark, NY-NJ-CT-PA                   | 22589036   | 995839 | 47272  | 26.377356402521        | 7.9%                 | 1               | 26         | 2.0         | 29.0       |
| 406      | New Orleans-Metairie-Hammond, LA-ME            | 1507017    | 46757  | 1811   | 31.026192803399        | 3.9%                 | 37              | 12         | 24.0        | 73.0       |
| 176      | Chicago-Naperville, IL-IN-WI                   | 9825325    | 207864 | 7527   | 21.1559414065184       | 3.6%                 | 3               | 53         | 31.0        | 87.0       |
| 148      | Boston-Worcester-Providence, MA-NH-RI          | 8287710    | 145451 | 9528   | 17.5502038560712       | 6.6%                 | 6               | 76         | 6.0         | 88.0       |
| 365      | Indianapolis-Elkhart, IN                       | 933340     | 30690  | 1301   | 32.881907963715        | 4.2%                 | 61              | 9          | 19.0        | 89.0       |
| 429      | Phoenix-Mesa, AZ                               | 5002221    | 149975 | 3229   | 29.182037339014        | 2.2%                 | 13              | 15         | 72.0        | 100.0      |
| 428      | Philadelphia-Reading-Camden, PA-NJ-DE          | 7209620    | 111602 | 7006   | 15.4795953184773       | 6.3%                 | 9               | 86         | 7.0         | 102.0      |
| 370      | Miami-Fort St. Lucie-Fort Lauderdale, FL       | 6889936    | 291586 | 5359   | 42.3205672737744       | 1.8%                 | 10              | 3          | 96.0        | 109.0      |
| 220      | Detroit-Warren-Ann Arbor, MI                   | 5341994    | 71600  | 5610   | 13.9648238732547       | 7.5%                 | 12              | 98         | 4.0         | 114.0      |
| 546      | Washington-Baltimore-Arlington, DC-MD-VA-WV    | 9814928    | 175048 | 5481   | 17.834873572175        | 3.1%                 | 4               | 73         | 40.0        | 117.0      |
| 154      | Brownsville-Harlingen-Raymondville, TX         | 444521     | 22233  | 817    | 50.0156348069045       | 3.7%                 | 94              | 2          | 30.0        | 126.0      |
| 348      | Los Angeles-Long Beach, CA                     | 18711436   | 406782 | 8777   | 21.739753164856        | 2.2%                 | 2               | 51         | 78.0        | 131.0      |
| 294      | Indianapolis-Carmel-Muncie, IN                 | 2457286    | 77931  | 1657   | 15.43613639075         | 4.4%                 | 28              | 87         | 17.0        | 132.0      |
| 484      | San Antonio-New Braunfels-Pearland, TX         | 2571266    | 54565  | 1392   | 21.2210638650377       | 2.6%                 | 25              | 52         | 56.0        | 133.0      |
| 508      | Shreveport-Bossier City-Minden, LA             | 433046     | 12168  | 469    | 28.0986315541536       | 3.9%                 | 95              | 19         | 25.0        | 139.0      |
| 122      | Atlanta-Athens-Clarke County-Sandy Springs, GA | 6851392    | 155277 | 3094   | 22.659558548526        | 2.0%                 | 11              | 43         | 86.0        | 140.0      |
| 296      | Jackson-Vicksburg-Brookhaven, MS               | 674340     | 18899  | 530    | 28.0295216419017       | 2.8%                 | 74              | 20         | 47.0        | 141.0      |
| 476      | St. Louis-St. Charles-Farmington, MO-IL        | 2907648    | 49406  | 1414   | 16.99174040324         | 2.9%                 | 20              | 79         | 44.0        | 143.0      |
| 318      | Lafayette-Opelousas-Morgan City, LA            | 620679     | 22727  | 578    | 36.616350802911        | 2.5%                 | 81              | 5          | 57.0        | 143.0      |
| 288      | Houston-The Woodlands, TX                      | 7253193    | 162538 | 3135   | 22.4091631773226       | 1.9%                 | 8               | 46         | 90.0        | 144.0      |
| 332      | Las Vegas-Henderson, NV                        | 2313238    | 60329  | 1171   | 26.078932059736        | 1.9%                 | 29              | 27         | 89.0        | 145.0      |
| 278      | Hartford-East Hartford, CT                     | 1470083    | 17823  | 1790   | 12.1238052545332       | 10.0%                | 41              | 113        | 1.0         | 155.0      |
| 536      | Tucson-Nogales, AZ                             | 1093777    | 24204  | 631    | 22.128825162716        | 2.6%                 | 54              | 49         | 52.0        | 155.0      |
| 163      | Cape Coral-Fort Myers-Naples, FL               | 1197501    | 32796  | 650    | 27.387033497258        | 2.0%                 | 48              | 22         | 87.0        | 157.0      |
| 379      | Winnipeg-St. Paul, MN-WI                       | 4027861    | 60723  | 1588   | 15.0757436763582       | 2.6%                 | 16              | 90         | 51.0        | 157.0      |
| 273      | Greenville-Spartanburg-Anderson, SC            | 1475235    | 28889  | 751    | 19.6504285757862       | 2.6%                 | 40              | 62         | 55.0        | 157.0      |
| 388      | Montgomery-Selma-Alexander City, AL            | 461516     | 15307  | 371    | 33.1667807833315       | 2.4%                 | 91              | 8          | 62.0        | 161.0      |
| 414      | North Port-Sarasota, FL                        | 1063906    | 22109  | 609    | 20.7809712512196       | 2.8%                 | 56              | 56         | 49.0        | 161.0      |
| 216      | Denver-Aurora, CO                              | 3617927    | 41398  | 1556   | 11.4424641514326       | 3.8%                 | 17              | 119        | 27.0        | 163.0      |
| 204      | Corpus Christi-Kingsville-Alice, TX            | 535257     | 18817  | 422    | 35.1500750387197       | 2.2%                 | 86              | 7          | 71.0        | 164.0      |
| 192      | Columbia-Orangeburg-Newberry, SC               | 963048     | 24642  | 539    | 25.3875096568395       | 2.2%                 | 60              | 31         | 73.0        | 164.0      |
| 422      | Orlando-Lakeland-DeLima, FL                    | 4166546    | 94297  | 1534   | 22.6640286147872       | 1.6%                 | 15              | 42         | 107.0       | 164.0      |
| 184      | Cleveland-Akron-Canton, OH                     | 3586918    | 32877  | 1417   | 9.16580752612689       | 4.3%                 | 18              | 138        | 18.0        | 174.0      |
| 279      | Hattiesburg-Laurel, MS                         | 253330     | 7428   | 210    | 29.3214384399795       | 2.8%                 | 121             | 14         | 45.0        | 180.0      |
| 384      | Monroe-Ruston, LA                              | 247003     | 7967   | 225    | 32.2546689716319       | 2.8%                 | 123             | 11         | 46.0        | 180.0      |
| 348      | Memphis-Forest City, TN-MS-AR                  | 1371039    | 561    | 29     | 179330402142           | 1.4%                 | 43              | 16         | 125.0       | 184.0      |
| 324      | Lake Charles-Jennings, LA                      | 241777     | 8815   | 229    | 36.4592165507885       | 2.6%                 | 125             | 6          | 53.0        | 184.0      |

Figure 1: CSA ranking and choice

## 3 Criterion: choice of day 0

We present now the algorithm (Algorithm 1) which implements the criterion to choose “day 0” (starting date of the exponential phase of community transmission). The output will be the ideal “day 0” to start the fit.

- Line 1: we require the CSA incidence data  $D$  as input.
- Line 2-3: As first steps, we calculate the 7-day lagged moving average of the incidence data (line 2), using the function  $M_7$ , and we round its value (line 3). The function  $M_7$  calculates the 7-day lagged moving average:

$$m(i) = \frac{1}{7} \sum_{i}^{i+6} D(i)$$

for  $i = 0, \dots, \text{length}(D)-6$ .

*Note: we round the values to have a curve that resembled a step function at the beginning, when cases were relatively small, to have a bigger error in the fit of the exponential curve.*

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**Algorithm 1:** “Day 0” criterion implementation

---

```
1 Input  $D$ 
2  $m = M_7(D)$ 
3  $r = \text{round}(m)$ 
4  $v_{\text{ex}} = v_e = v_d = c()$ 
5  $j = \min\{i : (r[i] > 0)\}$ 
6  $k = j + 15$ 
7 for  $i$  in  $j : k$  do
8    $b = i$ 
9    $e = i + 14$ 
10   $l = lm(\log(r[b : e]) \sim c(1 : 15))$ 
11   $v_{\text{ex}} = c(v_{\text{ex}}, \alpha)$  #  $\alpha$ :  $\text{coeff}(l)[2]$ 
12   $\epsilon = \sum_{h=1}^{15} |rl[h]|$ 
13   $v_e = c(v_e, \epsilon)$ 
14   $v_d = c(v_d, i)$ 
15 if  $\max(v_{\text{ex}}) > 0.25$  then
16    $\alpha_m = 0.25$ 
17 else if  $\max(v_{\text{ex}}) > 0.2$  then
18    $\alpha_m = 0.2$ 
19 else
20   return NA
21  $\text{ind} = \text{which}(v_e = \min(v_e))$  # i.e.  $i : v_e[i] = \min(v_e)$ 
22 while  $v_{\text{ex}}[\text{ind}] < \alpha_m$  do
23    $v_e = v_e[-\text{ind}]$ 
24    $v_{\text{ex}} = v_{\text{ex}}[-\text{ind}]$ 
25    $v_d = v_d[-\text{ind}]$ 
26    $\text{ind} = \text{which}(v_e = \min(v_e))$ 
27 return  $v_d[\text{ind}]$ 
```

---

*There were cases where the best fit was given by the very beginning of the time series, with a very few cases at the end, which was not ideal. With the round option, we got better ranges, with higher number of cases and a good fit of the exponential curve.*

- Line 4: we define 3 empty vectors  $v_{\text{ex}}$ ,  $v_e$  and  $v_d$  that will be used to collect the fit parameters, the error of the fit and the corresponding initial day of the range, respectively.
- Line 5-6: to select which days to consider to search for an appropriate 15-day range, we start with the first day for which the round number of the 7-day lagged moving average  $r$  is above 0, and try from that day, for 16 consecutive days.
- Line 7-14: in this for loop, we fit a linear model to the logarithm of  $r$  for different 15-day ranges and we collect the fit parameter  $\alpha$ , the error of the fit  $\epsilon$  (residuals) and the corresponding initial day for each considered range. The output of the fit gives the coefficients  $\beta$  and  $\alpha$  (fit:  $\log(\beta) + \alpha x$ ). If we consider  $r$  instead of its logarithm, we can write the function:  $\beta e^{\alpha x}$ . Note that we use a syntax similar to the programming language R, using the function  $lm$  to indicate the fitting procedure and the function  $c()$  to indicate the concatenation of two vectors (in this case we expand the existing vectors with additional elements).
- Line 15-20: depending on the maximum value of  $v_{\text{ex}}$  (vector of coefficients  $\alpha$ ), we assign different values to  $\alpha_m$ , which will be used in the while loop in line 22-26. If the maximum value results below 0.2, we return NA. We chose these values to have a threshold on the exponential growth, to capture a sufficiently vigorous epidemics near the start of the COVID-19 pandemic.<sup>1</sup>
- Line 21: we select the index which corresponds to the minimum error.
- Line 22-26: we look for the index corresponding to the lowest error and a coefficient  $\alpha$  above  $\alpha_m$ . While the condition on the coefficient  $\alpha$  is not satisfied, we keep searching for the desired index by removing the already considered elements in the vectors  $v_e$ ,  $v_{\text{ex}}$  and  $v_d$ . The selected “day 0” will be given by  $v_d[\text{ind}]$ .

## 4 Chosen CSAs

Given the “day 0” criterion, the final choice of the CSAs presents 29 CSAs. Using this criterion we excluded 3 CSAs which did not present a sufficiently high coefficient  $\alpha$  to satisfy our criterion: Corpus Christi-Kingsville-Alice, TX, McAllen-Edinburg, TX and Montgomery-Selma-Alexander City, AL.

The extracted dates are presented and shown in Table 1 (number of days after the first day of data collection - 21 Jan 2020: 41, 49, 56, 50, 40, 43, NA, 41, 50, 50, 49, 48, 47, 46, 52, 43, 44, NA, 48, 44, NA, 45, 42, 48, 47, 46, 46, 50, 48, 47, 49, 40)

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<sup>1</sup>Note that for the calculation of the growth rate and therefore of  $R_0$  we used the output of our SCLAIV+D model simulation. Therefore, the extracted growth rate did not have necessarily to respect the threshold for the “day 0” choice, as we observe for the Tucson-Nogales, AZ results, with extracted growth rate  $r = 0.12$

| List number | CSA   | Chosen day 0 |
|-------------|---|--------------|
| 1           | Atlanta-Athens-Clarke County-Sandy Springs, GA-AL | 1 March      |
| 2           | Boston-Worcester-Providence, MA-RI-NH-CT          | 9 March      |
| 3           | Brownsville-Harlingen-Raymondville, TX            | 16 March     |
| 4           | Cape Coral-Fort Myers-Naples, FL                  | 10 March     |
| 5           | Chicago-Naperville, IL-IN-WI                      | 29 February  |
| 6           | Columbia-Orangeburg-Newberry, SC                  | 3 March      |
| 7           | Corpus Christi-Kingsville-Alice, TX               | -            |
| 8           | Denver-Aurora, CO                                 | 1 March      |
| 9           | Detroit-Warren-Ann Arbor, MI                      | 10 March     |
| 10          | Greenville-Spartanburg-Anderson, SC               | 10 March     |
| 11          | Hartford-East Hartford, CT                        | 9 March      |
| 12          | Houston-The Woodlands, TX                         | 8 March      |
| 13          | Indianapolis-Carmel-Muncie, IN                    | 7 March      |
| 14          | Jackson-Vicksburg-Brookhaven, MS                  | 6 March      |
| 15          | Lafayette-Opelousas-Morgan City, LA               | 12 March     |
| 16          | Las Vegas-Henderson, NV                           | 3 March      |
| 17          | Los Angeles-Long Beach, CA                        | 4 March      |
| 18          | McAllen-Edinburg, TX                              | -            |
| 19          | Miami-Port St. Lucie-Fort Lauderdale, FL          | 8 March      |
| 20          | Minneapolis-St. Paul, MN-WI                       | 4 March      |
| 21          | Montgomery-Selma-Alexander City, AL               | -            |
| 22          | New Orleans-Metairie-Hammond, LA-MS               | 5 March      |
| 23          | New York-Newark, NY-NJ-CT-PA                      | 2 March      |
| 24          | North Port-Sarasota, FL                           | 8 March      |
| 25          | Orlando-Lakeland-Deltona, FL                      | 7 March      |
| 26          | Philadelphia-Reading-Camden, PA-NJ-DE-MD          | 6 March      |
| 27          | Phoenix-Mesa, AZ                                  | 6 March      |
| 28          | San Antonio-New Braunfels-Pearsall, TX            | 10 March     |
| 29          | Shreveport-Bossier City-Minden, LA                | 8 March      |
| 30          | St. Louis-St. Charles-Farmington, MO-IL           | 7 March      |
| 31          | Tucson-Nogales, AZ                                | 9 March      |
| 32          | Washington-Baltimore-Arlington, DC-MD-VA-WV-PA    | 29 February  |

Table 1: Chosen “day 0” (starting date of the exponential phase of community transmission) for each CSA.

## 5 $R_0$ calculation

Table 1 in the main paper reports the values for  $R_0$  for each CSA considered in the analysis, given the generation time  $\mathcal{T}$ , equal to 5.40, as reported in (Rai et al., 2020), and the different epidemic growth rates  $r$ , as shown in Figure 2.

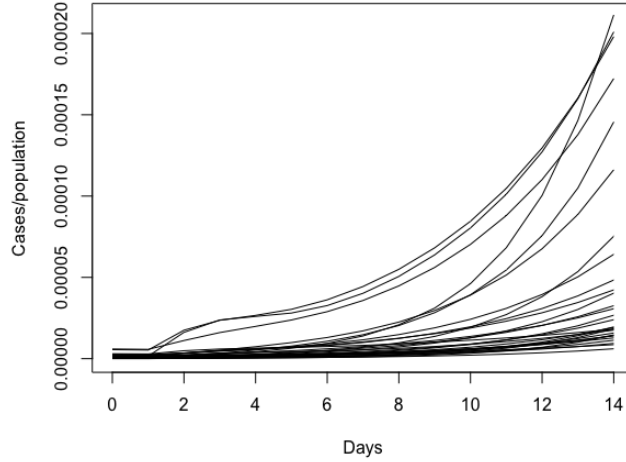


Figure 2: Exponential phase for each CSA. Population data downloaded from `data.census.gov`.

## 6 NMB-DASA web app: settings

In Figure 3 we provide the screenshots from the NMB-DASA web app to show the chosen parameters for the SCLAIV+D model and its fitting procedure. In particular, we chose:

- Infection rate reduction ( $\epsilon$ ): 0.75 (<https://www.cdc.gov/coronavirus/2019-ncov/hcp/planning-scenarios.html#table-1>, under “Infectiousness of asymptomatic individuals relative to symptomatic”, Scenario 5)
- Latent period ( $P_{\text{lat}}$ ): 4 (Getz et al., 2021)
- Asympt. period ( $P_{\text{asy}}$ ): 2.5 (A person with COVID-19 may be contagious 48 to 72 hours (2 to 3 days) before starting to experience symptoms. (<https://www.health.harvard.edu/diseases-and-conditions/covid-19-basics>))
- Infectious period ( $P_{\text{rec}}$ ): 7 (Getz et al., 2021)

We provide a separate supplementary online file SOF3 with the results of the Web App fits.

The screenshot shows two panels from the NMB-DASA web app. The top panel, titled 'Epidemic Parameters (fitting mode will vary Preferred on [Min, Max])', contains a table with columns for NAME, Effective pop. size ( $N_{eff}$ ), Contact rate param. ( $k$ ), Infection rate reduct. ( $\epsilon$ ), Succumb. period ( $P_{susc}$ ), Thwart period ( $P_{thw}$ ), Latent period ( $P_{lat}$ ), Asympt. period ( $P_{asymp}$ ), Infect. / Recov. period ( $P_{inf}$ ), Immunity period ( $P_{imm}$ ), Initial # of asymt. individs. ( $I_{init}$ ), Initial # of exposed individs. ( $E_{init}$ ), and Growth Est. ( $G_{est}$ ). The bottom panel, titled 'Epidemic Drivers (rows 2-4: switching functions in simulation mode)', contains a table with columns for NAME, Surveillance ( $\delta_{sur}$ ), Social distancing ( $\delta_{sd}$ ), Social Relaxation ( $\delta_{sl}$ ), Quarantining ( $\delta_{qua}$ ), Isolation / Treatment ( $\delta_{iso}$ ), Vaccination ( $\delta_{vac}$ ), Virulence ( $\delta_{vir}$ ), and Contact Rate reduction factor ( $\delta_{crr}$ ).

Figure 3: Screenshot from the NMB-DASA web app showing the chosen parameters

## 7 Clustering

In Algorithm 2 we present the calculation of the area under the curve, using the trapezoidal integration rule. The area under the curve is evaluated by dividing the total area into little trapezoids and summing their areas.

This procedure will return the list `area20` (line 2-4) which will contain 20 vectors of 29 entries, showing the cumulative value of the area under the curve for each CSA. We start with a vector of 29 entries, all equal to 0 (line 5). Given the list `ld` of the  $c_{flatten}(t)$  index for each CSA (line 8-9), we evaluate the area under the curve for each day starting for the last one corresponding to a  $c_{flatten}(t)$  index equal to 0 (line 10-11). We evaluate the area under the curve for every single day (considering two consecutive days for constructing the trapezoid, line 12-13). In the area calculation (line 14), `diff(x[id])` is always equal to 1 since we consider consecutive days, while `rollmean(y[id],2)` calculates the mean among the two considered values of the data ( $y$ ), for the given id (a rolling 2-day window). The area under the curve (AUC) is calculated and summed with the previous values (line 15), returning a cumulative evaluation for each curve (line 16) which presents the value of the area for each of the 20-day range, for each CSA.

We use these values (presented in Table 2) to cluster the different CSAs. In particular, we considered the area values for day 5, 10, 15 and 20, and used the elbow method to extract the number of clusters (as shown in Figure 4). With this analysis, we extracted two clusters. The 20-day range considered for each CSA, by group, is also shown in Figure 4.

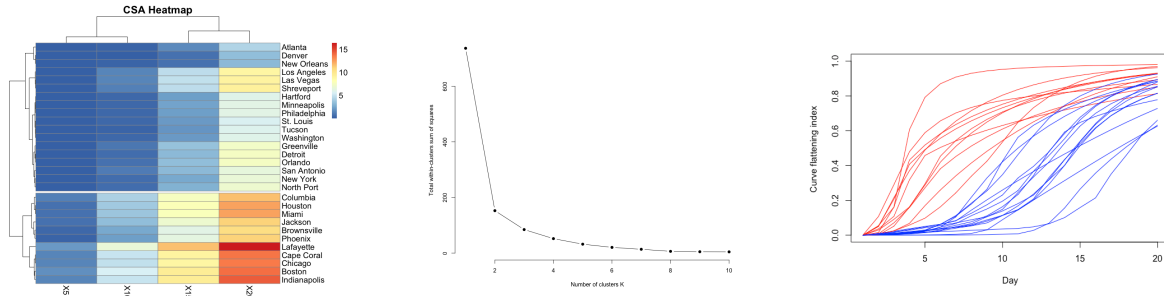


Figure 4: Heatmap and clusters of CSAs using 4 curve features (left). Elbow method results (center). The 20-day range considered for each CSA, by group (right).

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**Algorithm 2:**  $c_{\text{flatten}}$  area calculation implementation

---

```

1 Input ld (list of  $c_{\text{flatten}}(t)$  for each CSA)
2 area20 = list()
3 for  $i$  in 1:20 do
4    $\lfloor$  area20[[ $i$ ]] = vector()
5 area = rep(0, 29)
6 for  $i$  in 1:20 do
7   for  $j$  in 1:29 do
8      $y = \text{ld}[[j]]$ 
9      $x = 1:\text{length}(y)$ 
10    start = min(which( $y > 0$ ))
11    start = start - 1
12     $k = i-1$ 
13     $\text{id} = c(\text{start}+k, \text{start}+i)$ 
14     $\text{AUC} = \text{sum}(\text{diff}(x[\text{id}]) * \text{rollmean}(y[\text{id}], 2))$ 
15     $\text{area}[j] = \text{area}[j] + \text{AUC}$ 
16    $\text{area20}[[i]] = \text{area}$ 
17 return area20

```

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|              | X1                       | X2                      | X3                      | X4                      | X5                      | X6                      | X7                      | X8                      | X9                      | X10                     | X11                     | X12                     | X13  | X14   | X15  | X16   | X17   | X18   | X19   | X20   |
|--------------|--------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|------|-------|------|-------|-------|-------|-------|-------|
| Atlanta      | 2.76 · 10 <sup>-7</sup>  | 9.83 · 10 <sup>-5</sup> | 5.03 · 10 <sup>-4</sup> | 1.46 · 10 <sup>-3</sup> | 3.38 · 10 <sup>-3</sup> | 6.97 · 10 <sup>-3</sup> | 1.42 · 10 <sup>-2</sup> | 3.43 · 10 <sup>-2</sup> | 9.37 · 10 <sup>-2</sup> | 0.21                    | 0.38                    | 0.61                    | 0.9  | 1.24  | 1.64 | 2.09  | 2.59  | 3.14  | 3.75  | 4.4   |
| Boston       | 5.34 · 10 <sup>-2</sup>  | 0.25                    | 0.64                    | 1.17                    | 1.79                    | 2.47                    | 3.19                    | 3.94                    | 4.7                     | 5.48                    | 6.28                    | 7.08                    | 7.9  | 8.72  | 9.55 | 10.39 | 11.24 | 12.09 | 12.96 | 13.83 |
| Brownsville  | 3.22 · 10 <sup>-3</sup>  | 1.89 · 10 <sup>-2</sup> | 6.51 · 10 <sup>-2</sup> | 0.18                    | 0.4                     | 0.7                     | 1.08                    | 1.53                    | 2.04                    | 2.61                    | 3.24                    | 3.91                    | 4.63 | 5.39  | 6.18 | 7.01  | 7.87  | 8.75  | 9.65  | 10.56 |
| Cape Coral   | 2.7 · 10 <sup>-2</sup>   | 0.13                    | 0.43                    | 0.91                    | 1.46                    | 2.06                    | 2.72                    | 3.42                    | 4.16                    | 4.93                    | 5.72                    | 6.54                    | 7.38 | 8.23  | 9.11 | 9.99  | 10.89 | 11.81 | 12.73 | 13.66 |
| Chicago      | 2.59 · 10 <sup>-2</sup>  | 0.15                    | 0.46                    | 0.91                    | 1.44                    | 2.02                    | 2.65                    | 3.33                    | 4.04                    | 4.79                    | 5.57                    | 6.37                    | 7.2  | 8.04  | 8.91 | 9.79  | 10.69 | 11.6  | 12.53 | 13.46 |
| Columbia     | 1.79 · 10 <sup>-2</sup>  | 8.96 · 10 <sup>-2</sup> | 0.3                     | 0.69                    | 1.17                    | 1.69                    | 2.25                    | 2.84                    | 3.46                    | 4.1                     | 4.77                    | 5.45                    | 6.16 | 6.89  | 7.64 | 8.4   | 9.18  | 9.97  | 10.78 | 11.6  |
| Denver       | 5.95 · 10 <sup>-35</sup> | 2.05 · 10 <sup>-6</sup> | 2.26 · 10 <sup>-5</sup> | 1.15 · 10 <sup>-4</sup> | 3.92 · 10 <sup>-4</sup> | 1.05 · 10 <sup>-3</sup> | 2.39 · 10 <sup>-3</sup> | 4.83 · 10 <sup>-3</sup> | 8.9 · 10 <sup>-3</sup>  | 1.52 · 10 <sup>-2</sup> | 3.29 · 10 <sup>-2</sup> | 6.11 · 10 <sup>-2</sup> | 0.19 | 0.4   | 0.71 | 1.11  | 1.58  | 2.12  | 2.73  | 3.38  |
| Detroit      | 8.88 · 10 <sup>-4</sup>  | 6.67 · 10 <sup>-3</sup> | 2.03 · 10 <sup>-2</sup> | 4.15 · 10 <sup>-2</sup> | 7.3 · 10 <sup>-2</sup>  | 0.12                    | 0.19                    | 0.28                    | 0.42                    | 0.62                    | 0.9                     | 1.32                    | 1.85 | 2.48  | 3.19 | 3.96  | 4.78  | 5.64  | 6.52  | 7.42  |
| Greenville   | 5.08 · 10 <sup>-3</sup>  | 2.14 · 10 <sup>-2</sup> | 5.11 · 10 <sup>-2</sup> | 9.46 · 10 <sup>-2</sup> | 0.15                    | 0.22                    | 0.33                    | 0.48                    | 0.68                    | 0.96                    | 1.32                    | 1.76                    | 2.3  | 2.92  | 3.58 | 4.28  | 5     | 5.75  | 6.52  | 7.31  |
| Hartford     | 1.14 · 10 <sup>-3</sup>  | 4.53 · 10 <sup>-3</sup> | 1 · 10 <sup>-2</sup>    | 2.04 · 10 <sup>-2</sup> | 4.03 · 10 <sup>-2</sup> | 7.31 · 10 <sup>-2</sup> | 0.12                    | 0.18                    | 0.27                    | 0.41                    | 0.62                    | 0.89                    | 1.25 | 1.71  | 2.27 | 2.93  | 3.64  | 4.4   | 5.2   | 6.03  |
| Houston      | 1.46 · 10 <sup>-2</sup>  | 7.47 · 10 <sup>-2</sup> | 0.2                     | 0.43                    | 0.8                     | 1.3                     | 1.88                    | 2.52                    | 3.21                    | 3.93                    | 4.69                    | 5.47                    | 6.28 | 7.1   | 7.94 | 8.8   | 9.67  | 10.54 | 11.43 | 12.33 |
| Indianapolis | 2.45 · 10 <sup>-2</sup>  | 0.16                    | 0.45                    | 0.88                    | 1.41                    | 2.03                    | 2.72                    | 3.46                    | 4.24                    | 5.06                    | 5.91                    | 6.79                    | 7.68 | 8.59  | 9.52 | 10.45 | 11.4  | 12.35 | 13.31 | 14.27 |
| Jackson      | 3.54 · 10 <sup>-3</sup>  | 4.24 · 10 <sup>-2</sup> | 0.16                    | 0.37                    | 0.7                     | 1.12                    | 1.6                     | 2.14                    | 2.72                    | 3.35                    | 4.02                    | 4.72                    | 5.45 | 6.2   | 6.98 | 7.78  | 8.59  | 9.42  | 10.27 | 11.12 |
| Lafayette    | 7.34 · 10 <sup>-3</sup>  | 9.57 · 10 <sup>-2</sup> | 0.48                    | 1.18                    | 2.01                    | 2.9                     | 3.82                    | 4.75                    | 5.7                     | 6.66                    | 7.62                    | 8.59                    | 9.55 | 10.53 | 11.5 | 12.47 | 13.45 | 14.43 | 15.41 | 16.38 |
| Las Vegas    | 1.16 · 10 <sup>-3</sup>  | 6.05 · 10 <sup>-3</sup> | 1.6 · 10 <sup>-2</sup>  | 3.55 · 10 <sup>-2</sup> | 7.99 · 10 <sup>-2</sup> | 0.17                    | 0.31                    | 0.53                    | 0.88                    | 1.37                    | 1.97                    | 2.62                    | 3.33 | 4.07  | 4.84 | 5.65  | 6.48  | 7.34  | 8.21  | 9.1   |
| Los Angeles  | 6.51 · 10 <sup>-4</sup>  | 3.64 · 10 <sup>-3</sup> | 9.99 · 10 <sup>-3</sup> | 2.49 · 10 <sup>-2</sup> | 5.89 · 10 <sup>-2</sup> | 0.13                    | 0.3                     | 0.57                    | 0.95                    | 1.41                    | 1.94                    | 2.54                    | 3.2  | 3.9   | 4.65 | 5.44  | 6.26  | 7.11  | 7.99  | 8.88  |
| Miami        | 1.96 · 10 <sup>-8</sup>  | 2.58 · 10 <sup>-2</sup> | 0.13                    | 0.36                    | 0.71                    | 1.18                    | 1.73                    | 2.34                    | 3.02                    | 3.74                    | 4.51                    | 5.31                    | 6.14 | 6.99  | 7.86 | 8.75  | 9.65  | 10.57 | 11.49 | 12.43 |
| Minneapolis  | 1.31 · 10 <sup>-3</sup>  | 8.6 · 10 <sup>-3</sup>  | 2.49 · 10 <sup>-2</sup> | 4.96 · 10 <sup>-2</sup> | 8.22 · 10 <sup>-2</sup> | 0.12                    | 0.18                    | 0.25                    | 0.35                    | 0.48                    | 0.66                    | 0.93                    | 1.31 | 1.79  | 2.36 | 3.01  | 3.73  | 4.49  | 5.29  | 6.12  |
| New Orleans  | 2.14 · 10 <sup>-3</sup>  | 8.49 · 10 <sup>-3</sup> | 1.9 · 10 <sup>-2</sup>  | 3.34 · 10 <sup>-2</sup> | 5.17 · 10 <sup>-2</sup> | 7.39 · 10 <sup>-2</sup> | 9.98 · 10 <sup>-2</sup> | 0.13                    | 0.16                    | 0.2                     | 0.24                    | 0.3                     | 0.38 | 0.51  | 0.7  | 0.98  | 1.39  | 1.91  | 2.52  | 3.22  |
| New York     | 2.32 · 10 <sup>-3</sup>  | 1.32 · 10 <sup>-2</sup> | 3.62 · 10 <sup>-2</sup> | 7.17 · 10 <sup>-2</sup> | 0.12                    | 0.18                    | 0.26                    | 0.36                    | 0.48                    | 0.64                    | 0.85                    | 1.12                    | 1.5  | 1.99  | 2.58 | 3.26  | 4.02  | 4.83  | 5.69  | 6.59  |
| North Port   | 9.72 · 10 <sup>-4</sup>  | 3.85 · 10 <sup>-3</sup> | 1.01 · 10 <sup>-2</sup> | 2.25 · 10 <sup>-2</sup> | 4.49 · 10 <sup>-2</sup> | 8.36 · 10 <sup>-2</sup> | 0.14                    | 0.23                    | 0.35                    | 0.55                    | 0.84                    | 1.22                    | 1.69 | 2.27  | 2.93 | 3.66  | 4.44  | 5.25  | 6.09  | 6.96  |
| Orlando      | 1.36 · 10 <sup>-3</sup>  | 5.38 · 10 <sup>-3</sup> | 1.5 · 10 <sup>-2</sup>  | 3.27 · 10 <sup>-2</sup> | 6.62 · 10 <sup>-2</sup> | 0.12                    | 0.21                    | 0.34                    | 0.52                    | 0.74                    | 1.05                    | 1.47                    | 1.97 | 2.58  | 3.28 | 4.05  | 4.87  | 5.72  | 6.61  | 7.51  |
| Philadelphia | 8.46 · 10 <sup>-4</sup>  | 3.38 · 10 <sup>-3</sup> | 1.21 · 10 <sup>-2</sup> | 3.15 · 10 <sup>-2</sup> | 6.11 · 10 <sup>-2</sup> | 0.1                     | 0.15                    | 0.22                    | 0.32                    | 0.45                    | 0.62                    | 0.87                    | 1.21 | 1.68  | 2.27 | 2.94  | 3.68  | 4.48  | 5.31  | 6.18  |
| Phoenix      | 2.86 · 10 <sup>-3</sup>  | 1.82 · 10 <sup>-2</sup> | 5.96 · 10 <sup>-2</sup> | 0.14                    | 0.27                    | 0.47                    | 0.76                    | 1.14                    | 1.62                    | 2.22                    | 2.91                    | 3.67                    | 4.49 | 5.36  | 6.25 | 7.18  | 8.12  | 9.08  | 10.04 | 11.02 |
| San Antonio  | 3.08 · 10 <sup>-3</sup>  | 1.72 · 10 <sup>-2</sup> | 4.24 · 10 <sup>-2</sup> | 8.22 · 10 <sup>-2</sup> | 0.14                    | 0.21                    | 0.32                    | 0.5                     | 0.73                    | 1.01                    | 1.35                    | 1.74                    | 2.19 | 2.68  | 3.21 | 3.8   | 4.42  | 5.09  | 5.8   | 6.55  |
| Shreveport   | 4.07 · 10 <sup>-3</sup>  | 1.19 · 10 <sup>-2</sup> | 2.58 · 10 <sup>-2</sup> | 4.85 · 10 <sup>-2</sup> | 9.4 · 10 <sup>-2</sup>  | 0.18                    | 0.33                    | 0.55                    | 0.85                    | 1.26                    | 1.77                    | 2.4                     | 3.1  | 3.88  | 4.7  | 5.55  | 6.43  | 7.34  | 8.26  | 9.19  |
| St. Louis    | 1.18 · 10 <sup>-3</sup>  | 4.66 · 10 <sup>-3</sup> | 1.19 · 10 <sup>-2</sup> | 2.42 · 10 <sup>-2</sup> | 4.12 · 10 <sup>-2</sup> | 6.95 · 10 <sup>-2</sup> | 0.12                    | 0.19                    | 0.3                     | 0.44                    | 0.63                    | 0.87                    | 1.17 | 1.55  | 2.05 | 2.66  | 3.34  | 4.08  | 4.86  | 5.68  |
| Tucson       | 7.76 · 10 <sup>-4</sup>  | 3.09 · 10 <sup>-3</sup> | 6.93 · 10 <sup>-3</sup> | 1.23 · 10 <sup>-2</sup> | 2.14 · 10 <sup>-2</sup> | 3.6 · 10 <sup>-2</sup>  | 5.83 · 10 <sup>-2</sup> | 9.01 · 10 <sup>-2</sup> | 0.14                    | 0.22                    | 0.37                    | 0.59                    | 0.92 | 1.38  | 1.96 | 2.63  | 3.37  | 4.15  | 4.96  | 5.81  |
| Washington   | 1.99 · 10 <sup>-3</sup>  | 7.46 · 10 <sup>-3</sup> | 1.58 · 10 <sup>-2</sup> | 2.68 · 10 <sup>-2</sup> | 4.23 · 10 <sup>-2</sup> | 6.41 · 10 <sup>-2</sup> | 9.93 · 10 <sup>-2</sup> | 0.15                    | 0.24                    | 0.36                    | 0.53                    | 0.78                    | 1.12 | 1.56  | 2.12 | 2.77  | 3.5   | 4.28  | 5.1   | 5.95  |

Table 2: Values of the area for each CSA, in the considered 20-day range. The variable  $X_i$  represents the area under the curve after  $i$  days, starting from the last day with the index equal to 0. We coloured the table according to the values: the darker cells contain higher values.



## Additional clustering analysis

In this subsection we discuss some additional clustering analysis, considering area features and  $R_0$ , to provide further information. In Figure 5 (left) we also report the results for a choice of 3 clusters, considering the 4 area features. In Figure 5 (right) we report the 20-day range of interest, coloured by clusters, and observe that the strong social distancing response group was subdivided in strong (orange) and very strong (red) response. In Figure 6 we report the silhouette analysis: the average silhouette width suggests that the choice of two clusters, which is reported in the main paper, was more appropriate, as shown also by the elbow method. In addition, in Figure 7 we report the heatmap and clusters of CSAs considering all the 20 curve features. We observe that this choice yields the same extracted clusters as the ones reported in the main paper, which were extracted considering only 4 area features.

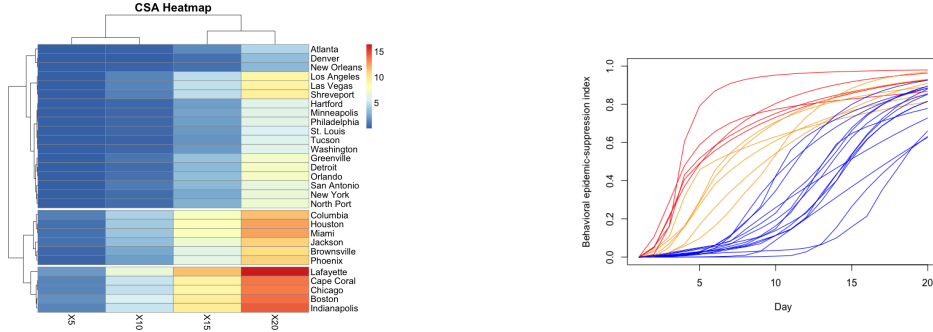


Figure 5: Heatmap and clusters of CSAs using 4 curve features (left), defining 3 clusters. 20-day range considered for each CSA, by group (right): weak (blue), strong (orange) and very strong (red) response.

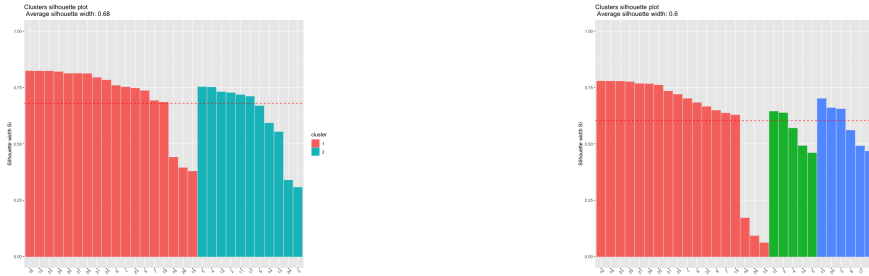


Figure 6: Silhouette information for the 2 clustering choices (2 and 3 clusters, considering the 4 area features). We observe a higher average silhouette width for the choice of 2 clusters (0.68 vs 0.60).

### Additional clustering analysis, considering also $R_0$

In Figure 8 (left) we report the results of the clustering analysis considering the 4 area features and  $R_0$ . To perform the clustering analysis we considered the z-score transformation of the variables. By looking at the scatter plot of total 20-day area and  $R_0$  in Figure 8 (right), we observe a clear separation of the 2 extracted clusters, with the area values being more influential to the clustering than  $R_0$ . The resulting clusters are the same as the previous analysis (considering only 4 area features), except for two CSAs (Brownsville-Harlingen-Raymondville, TX and Phoenix-Mesa, AZ).

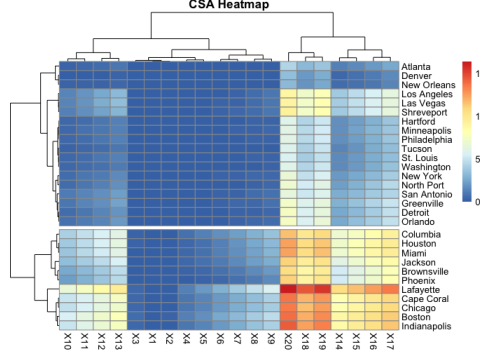


Figure 7: Heatmap and clusters of CSAs using all 20 curve features.

As shown in Figure 9, these two CSAs presented an intermediate behaviour and they are now clustered with the *weak* response group. In Figure 10 we report the silhouette analysis for 2 and 3 clusters, observing the same average silhouette width for the two choices. We then report the 3 cluster analysis in Figure 11, observing that the new cluster is formed by the 2 CSAs New York-Newark, NY-NJ-CT-PA and Phoenix-Mesa, AZ, which present a particularly high  $R_0$ . The other two clusters are the remaining weak vs strong social distancing response CSAs.

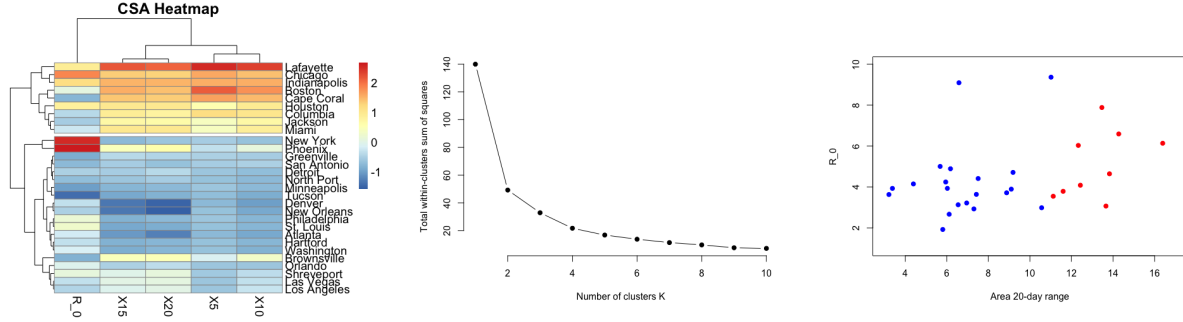


Figure 8: Heatmap and clusters of CSAs using 4 curve features and  $R_0$  (left), considering the z-score transformation of the variables. Number of clusters chosen by performing the elbow method (center). Scatter plot of total 20-day area and  $R_0$  (right), with CSA values coloured depending on the response: weak (blue) vs strong (red).

In Figure 12 we report the clustering analysis considering only two values: the final 20-day area value and  $R_0$  (considering the z-score transformation of the variables). Also in this case, in Figure 12 (right) we observe that the 3 clusters represent the CSAs depending on weak vs strong response and by high values of  $R_0$ . In Figure 13 we observe a higher average silhouette width reported for 3 clusters.

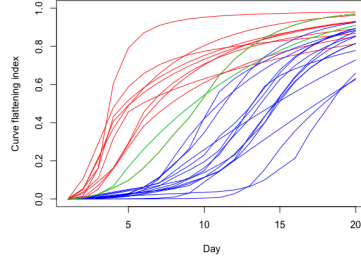


Figure 9: 20-day range considered for each CSA, by group: weak (blue and green) and strong (red) response. We indicate the indices of Brownsville-Harlingen-Raymondville, TX and Phoenix-Mesa, AZ in green to highlight their behaviour: it is intermediate between weak and strong response and now classified with the weak response group.



Figure 10: Silhouette information for 2 and 3 clusters, with the same average silhouette width for the two choices (0.57).

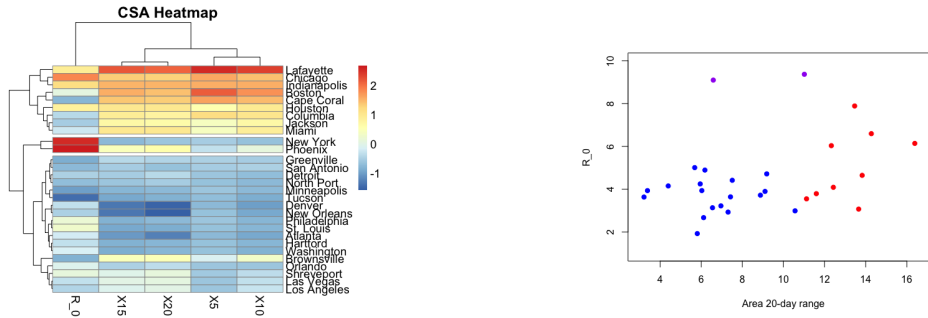


Figure 11: Heatmap showing the 3 clusters (left). Scatter plot of total 20-day area and  $R_0$  (right), with CSA values coloured depending on the response or  $R_0$ : weak (blue) vs strong (red) response, and particularly high  $R_0$  value (purple).

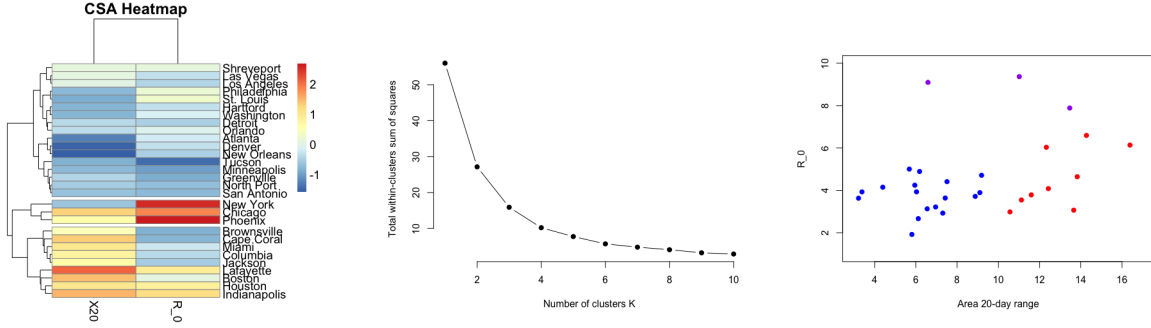


Figure 12: Heatmap and clusters of CSAs using the total 20-day area and  $R_0$  (left), considering the z-score transformation of the variables. Number of clusters chosen by performing the elbow method (center). We observe a similar separation (right) as in Figure 8, with an additional separate cluster for the 3 CSAs reporting a high value of  $R_0$  (Chicago-Naperville, IL-IN-WI, New York-Newark, NY-NJ-CT-PA and Phoenix-Mesa, AZ)

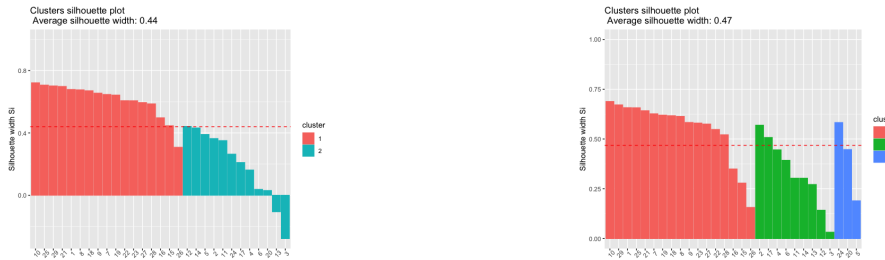


Figure 13: Silhouette information for the clustering of total 20-day area and  $R_0$ . We observe a higher average silhouette width for 3 clusters (0.47 vs 0.44).

## References

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