ESPON

EUROPEAN UNION

Co-financed by the European Regional Development Fund

Inspire Policy Making with Territorial Evidence

FINAL REPORT //

Territorial impacts of COVID-19 and policy answers in European regions and cities

Spatial diffusion of COVID-19

Annex 1 // June 2022

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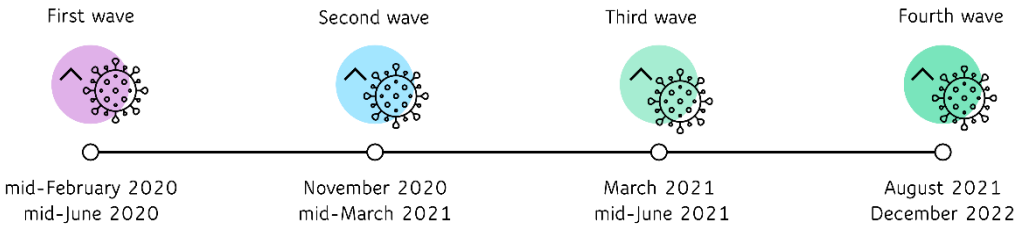
1 Spatial diffusion of COVID-19 across European regions: A country-perspective

As part of the ESPON COVID-19 project, the spatial diffusion of the COVID-19 pandemic across European regions was mapped and analysed (Box 1-21). The analysis takes three variables, the first is time-related whereby the same time frame for the consecutive waves as reported in the final report was used (Figure 1). The second is typology-related (urban, rural, and intermediate) for all European regions, and the third is the number of COVID-19 cases collected at NUTS3 level. Notice that countries that are considered as NUTS1/NUTS3 (Malta, Cyprus, etc.) at the same time are dropped from the analysis as we need to have different regions within each country. Countries with NUTS2 (Poland, Greece) data are also excluded as regional typologies are established only at NUTS3 level.

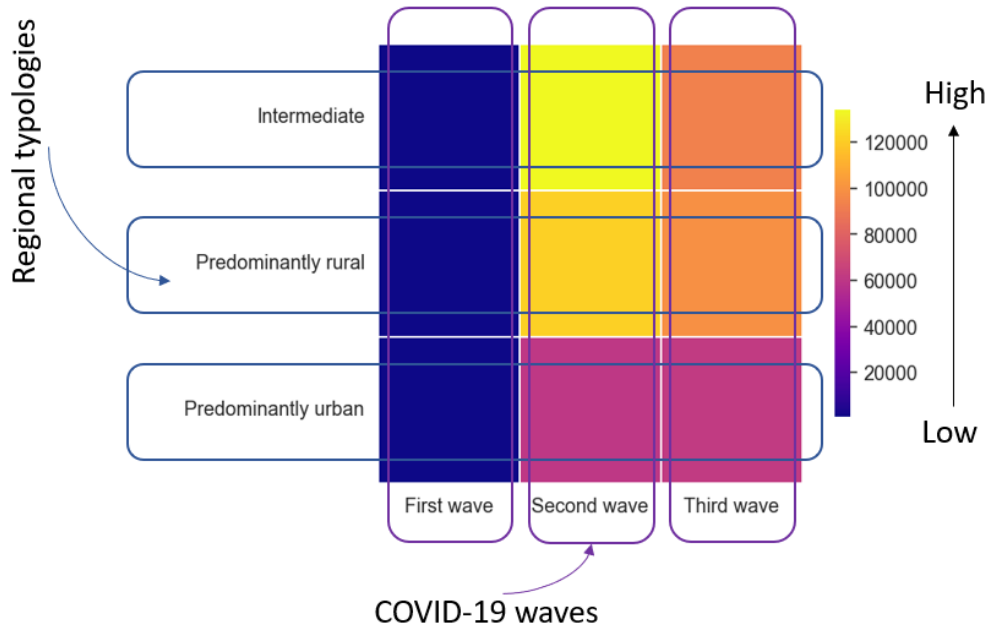
Figure 1 Time-frames of the COVID-19 waves across Europe



The analysis follows the same structure based around three major points:

- **Internal-spatial diffusion:** Mapping the spatial diffusion of the COVID-19 infection cases within a given country across the three waves.
- **COVID-19 internal-regional evolution:** Inspect how regional typologies have experienced COVID-19 infections and draw the major pattern.
- **COVID-19 internal-spatiotemporal comparison:** Compare regions of the same country and during the three fist waves (Figure 2).

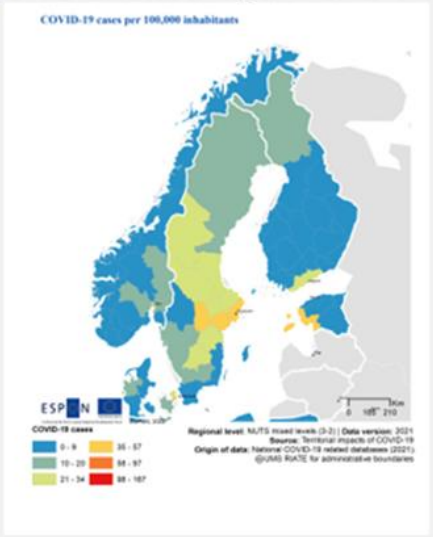
Figure 2 Boxes interpretation



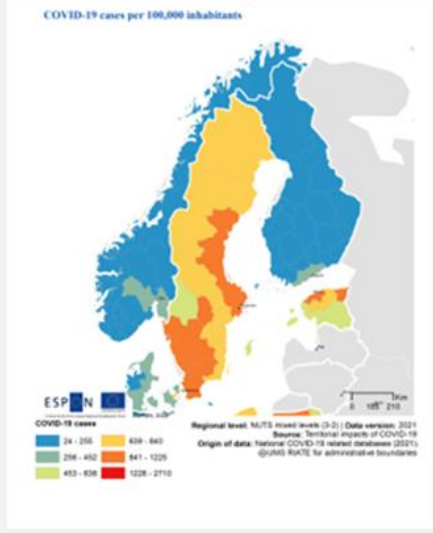
In each box below, the figure on the right side of the box represents the number of cases per type of region and wave.

Box 1 - Spatial diffusion of the COVID-19 in the Northern region (case of Sweden)

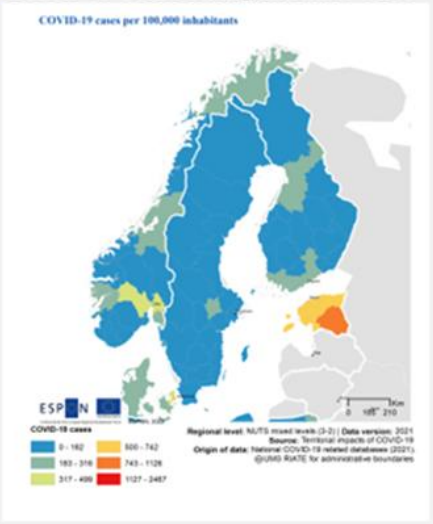
COVID-19 cases during the first wave

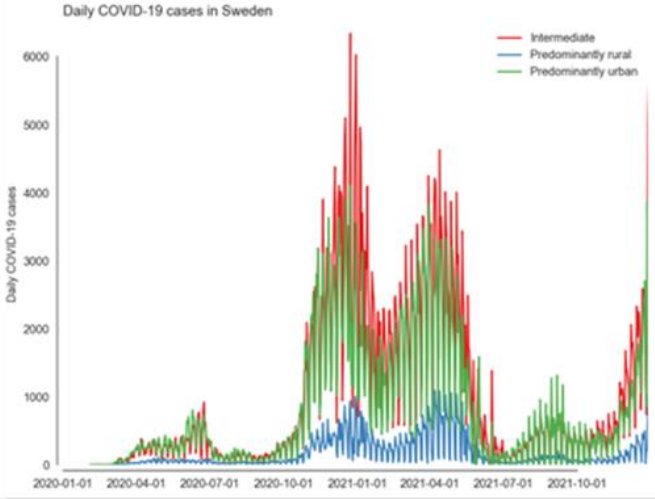


COVID-19 cases during the second wave



COVID-19 cases during the third wave





The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, Sweden saw mainly **four COVID-19 waves**; in which the first reached the peak on June, 16, 2020, the second on January, 11, 2021, the third on April, 17, 2021 and the fourth on November, 23, 2021.

During the first wave, both predominantly urban regions (e.g., Stockholms län and Västra Götalands län counting the highest number of COVID-19 infections) and intermediate regions (e.g., Östergötlands län, Södermanlands län, and Örebro län) were hit almost with the same magnitude; however, predominantly rural areas were less hit by the virus compared to other types of regions (e.g., Dalmas län and Jämtlands lån).

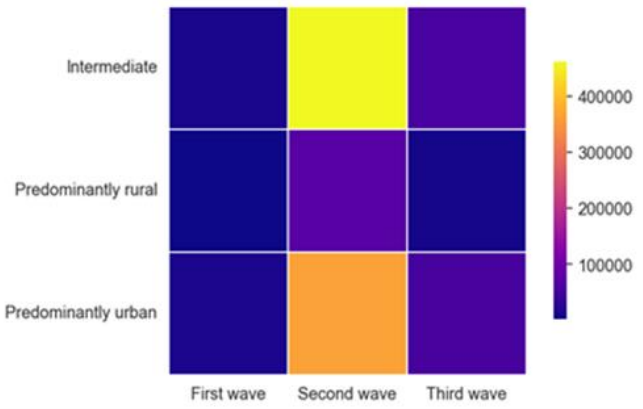
During the second wave, the virus spread to all Swedish regions. Intermediate regions (e.g., Skane län, Hallands län, and Jököpings län) were hit more than urban regions. Therefore, Sweden

During the third wave, the infection number across regions decreases mostly because of the implementation of severe lockdown measures where urban and intermediate regions are hit almost with the same magnitude.

When taking population dynamics and regional characteristics into account, we found that urban areas represent 9% of Swedish regions and host 41% of the total Swedish population, while intermediate regions represent 70% and host 51% of the total population, and rural areas represent 24% and host only 8% of the total population. Therefore, intermediate regions are more likely to get hit by the virus considering their number and share of the total Swedish population.

Figure down below (the cube) shows COVID-19 cases magnitude during the three waves and disaggregated by types of regions.

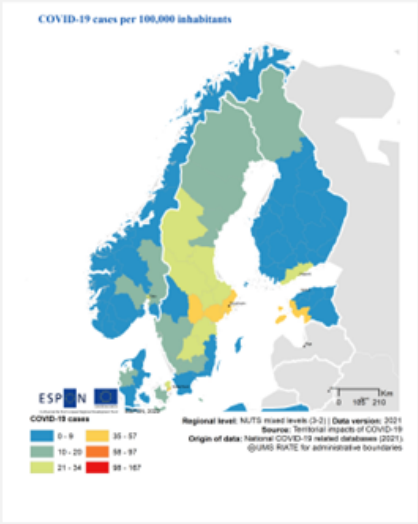
Overall, Swedish intermediate regions were the most hit by the virus (50.76% of the total cases), followed by predominantly urban (41.22%) and predominantly rural areas (8%), respectively.



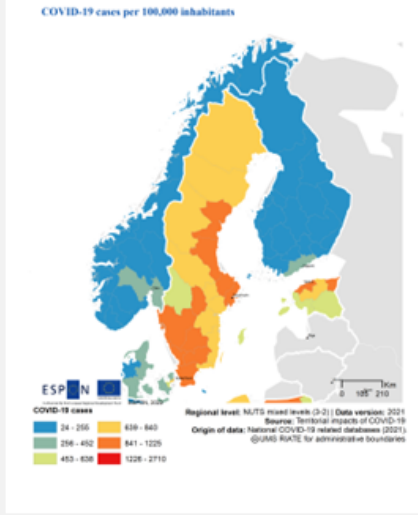
Total COVID-19 cases		Number of regions	Data source
22-06-2022 2.51M	**Sweden**	21 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 2 - Spatial diffusion of the COVID-19 in the Northern region (case of Norway)

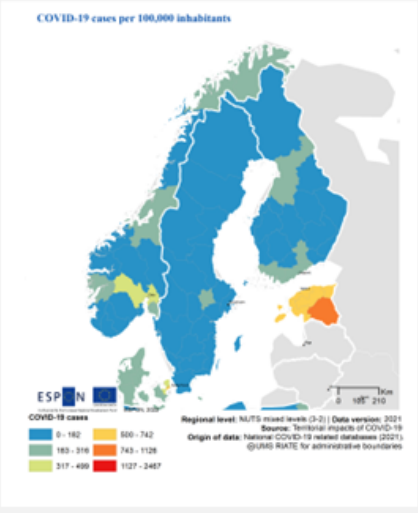
COVID-19 cases during the first wave

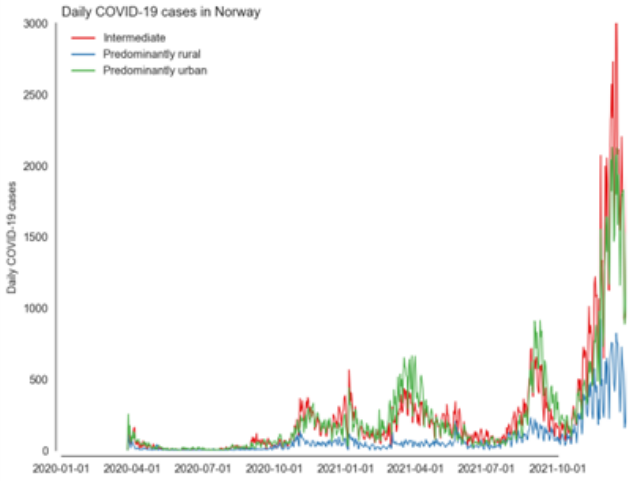


COVID-19 cases during the second wave



COVID-19 cases during the third wave





The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, Norway saw mainly **five COVID-19 waves**; in which the first reached the peak on March, 15, 2020, the second on January, 02, 2021, the third on March, 26, 2021, the fourth on November, 18, 2021, and the fifth on December 21, 2021.

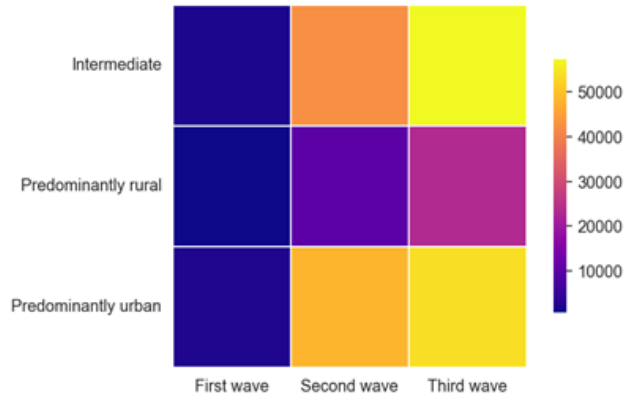
During the first wave, both intermediate and predominantly urban regions of Norway were the most affected by the pandemic as reported in Oslo and Akershus (urban regions), followed by the intermediate regions such as Hordaland, Buskerud, Trøndelag.

During the second wave, the infection numbers of COVID-19 started to increase in intermediate regions (e.g., Østfold, Buskerud, Hordaland, and Rogaland) and predominantly urban regions (e.g., Oslo, and Akershus). During the three waves, predominantly rural regions were less hit by the virus (e.g., Hedmark).

During the third wave, COVID-19 cases increases across all regions, espacially for intermediate regions such as in Trøndelag, Hordaland, Buskerud, and Østfold.

When taking population dynamics and regional characteristics into account, we found that predominantly urban regions represent 12% of the total regions and host 25% of the total population, while intermediate regions represent 44% and host 50% of the total population of Norway. Predominantly rural regions represent 26% but only host 13% of the total population of Norway. Therefore, intermediate and predominantly urban regions are more likely to get hit by the virus considering their share of the total population and regional distribution.

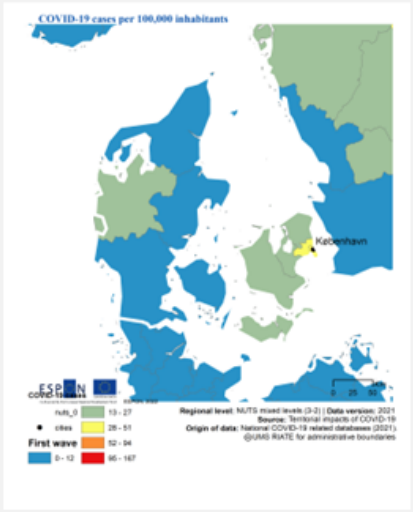
Overall, predominantly urban regions were the most hit by the virus (counting 46% of the total cases across the three waves), followed by intermediate regions (40%) and predominantly rural regions (14%).



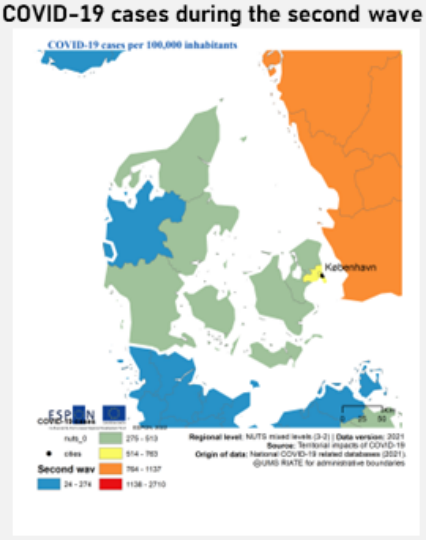
Total COVID-19 cases	Norway	Number of regions	Data source
22-06-2022 1.44M		18 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 3 - Spatial diffusion of the COVID-19 in the Northern region (case of Denmark)

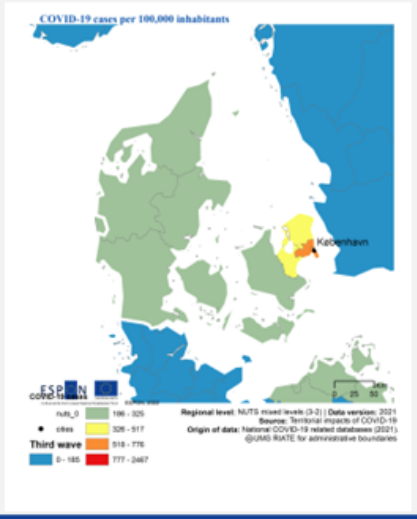
COVID-19 cases during the first wave

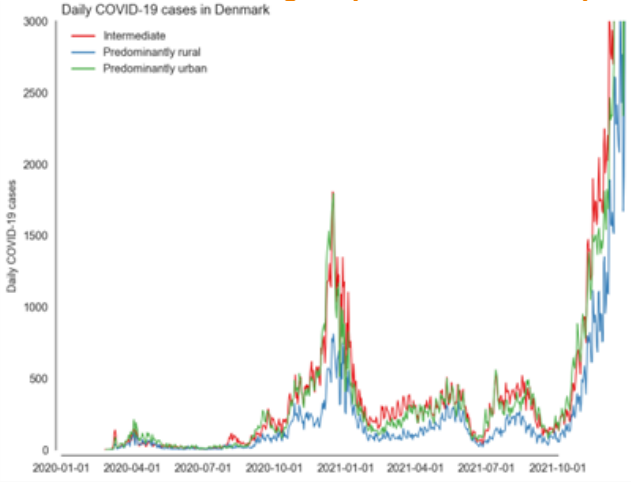


COVID-19 cases during the second wave



COVID-19 cases during the third wave





During the study timeframe, Denmark saw mainly **four COVID-19 waves**; in which the first reached the peak on March, 13, 2020, the second on December, 26, 2020, the third on July, 08, 2021, and the fourth on December, 21, 2021.

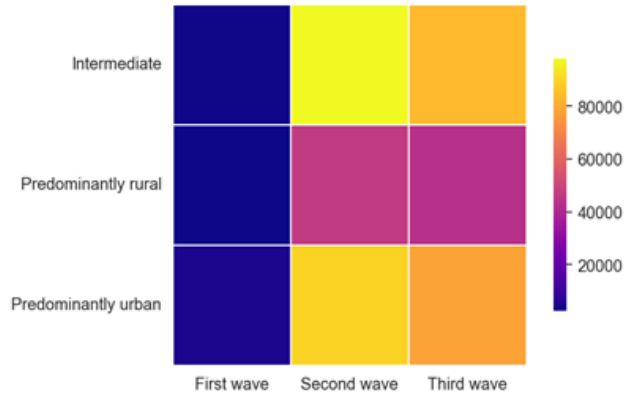
During the first wave, predominantly urban regions of Denamrk were the most affected by the pandemic as reported in Byen København, and Københavns omegn. During the first wave a hierarchical diffusion model was triggered in Denamrk whereby the urban regions were hit the first and then intermediate (Nordsjælland) and rural areas (Vest- og Sydsjælland).

During the second wave, the infection number of COVID-19 started to increase following the same regional pattern of the first wave (urban and intermediate regions) as reported during the first wave. However, the infection growth rates started escalating in intermediate regions as reported in Østjylland, Nordsjælland, Sydjylland, and Fyn.

During the third wave, and following the same hierarchical diffusion spotted during the first and second wave, the infection numbers in Denmark decreased especially in predominantly urban regions.

When taking population dynamics and regional characteristics into account, we found that predominantly urban regions represent 18% of the total regions and host 23% of the total population, while intermediate regions represent 45% and host 48% of the total population in Denmark. Predominantly rural regions represent 36% but only host 28% of the total population of Denmark. Therefore, intermediate regions are more likely to get hit by the virus considering their share of the total population and regional distribution.

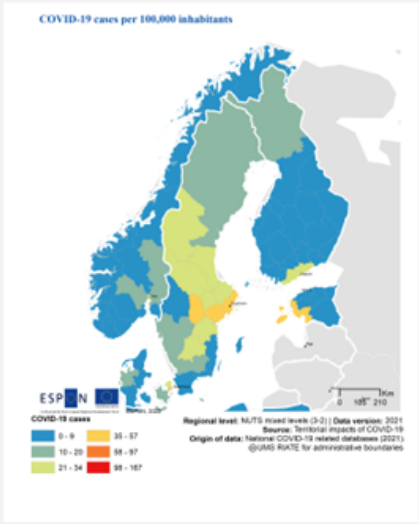
Overall, intermediate regions were the most hit by the virus (counting 41% of the total cases across the three waves), followed by predominantly urban regions (38%) and predominantly rural regions (20%).



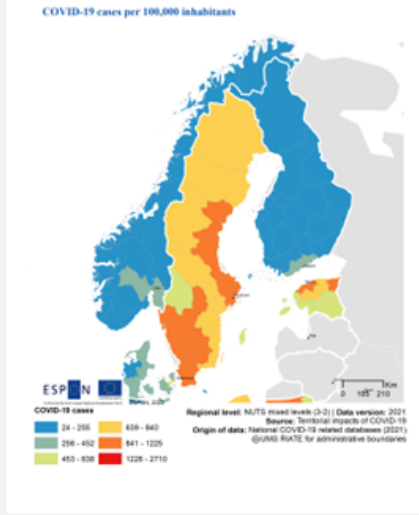
Total COVID-19 cases		Number of regions	Data source
22-06-2022 3.16M	**Denmark**	11 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 4 - Spatial diffusion of the COVID-19 in the Northern region (case of Finland)

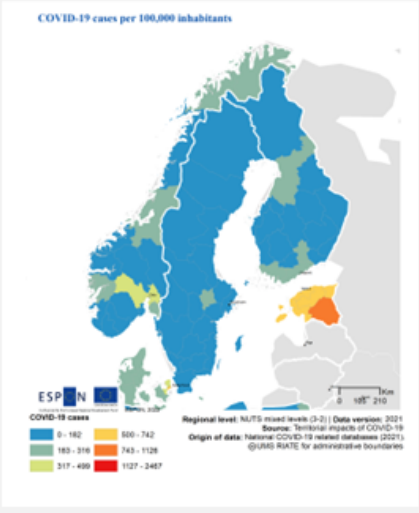
COVID-19 cases during the first wave

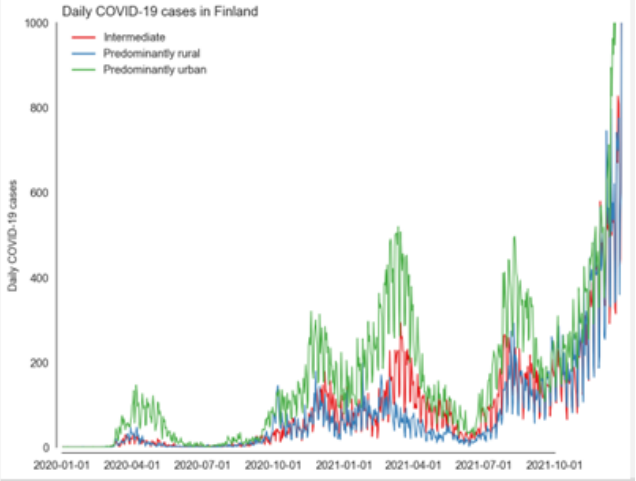


COVID-19 cases during the second wave



COVID-19 cases during the third wave





During the study timeframe, Finland saw mainly **four COVID-19 waves**; in which the first reached the peak on March, 24, 2020, the second on December, 11, 2020, the third on March, 13, 2021, and the fourth on August, 13, 2021.

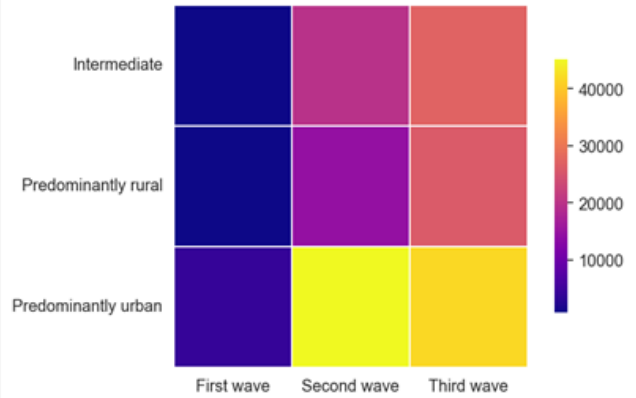
During the first wave, the region of Helsinki-Uusimaa accounted for the highest number of infections cases, followed by two intermediates regions of Varsinais-Suomi, Pirkanmaa, followed by predominantly rural regions of Lappi, Keski-Suomi, Pohjois-Pohjanmaa, Pohjois-Savo.

During the second wave, the infection number of COVID-19 started to increase in predominantly urban regions (i.g., Helsinki-Uusimaa) but also for intermedaite regions (e.g., Varsinais-Suomi, and Pirkanmaa), and predominantly rural areas (e.g., Pohjois-Pohjanmaa, Pohjanmaa, Keski-Suomi).

During the third wave, COVID-19 cases decreases across all regions, espacially for urban regions such as in Helsinki-Uusimaa, but also for intermediate regions e.g., Varsinais-Suomi, and Pirkanmaa. And also for redominantly rural regions such as Pohjois-Pohjanmaa.

When taking population dynamics and regional characteristics into account, we found that predominantly rural regions represent 63% of the total regions and host 39% of the total population, while intermediate regions represent 32% and host 30% of the total population of Finland. Predominantly urban regions represent 5% but only host 13% of the total population of Finland. Therefore, intermediate and predominantly urban regions are more likely to get hit by the virus considering their share of the total population and regional distribution.

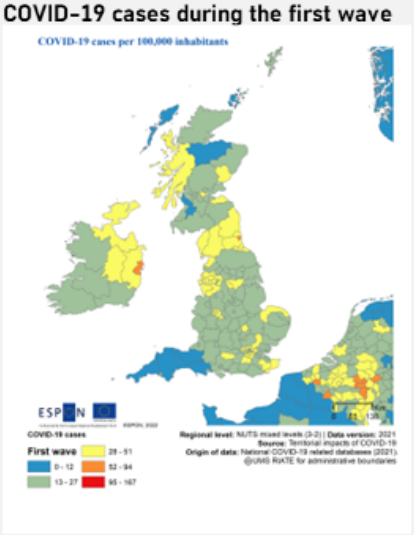
Overall, predominantly urban regions were the most hit by the virus (counting 51% of the total cases across the three waves), followed by predominantly rural regions (23%) and intermediate regions (26%).



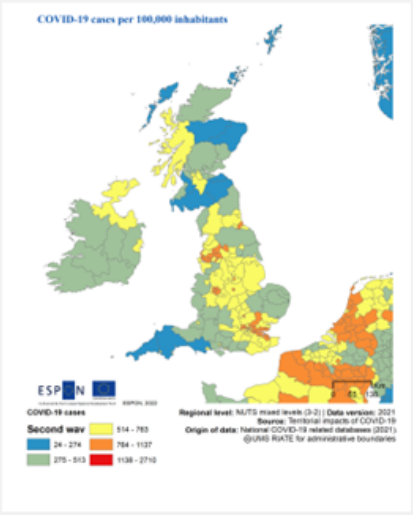
Total COVID-19 cases		Number of regions	Data source
22-06-2022 1.13M	**Finland**	19 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 5 - Spatial diffusion of the COVID-19 in the British Isles region (case of the UK)

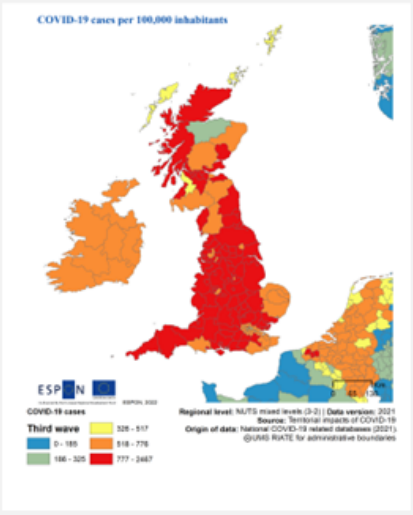
COVID-19 cases during the first wave

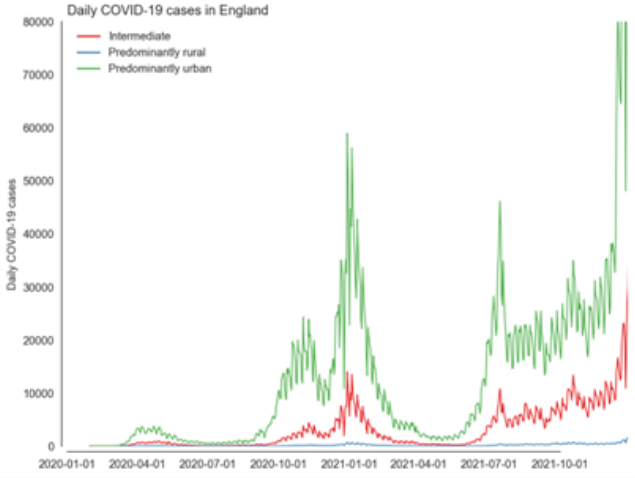


COVID-19 cases during the second wave



COVID-19 cases during the third wave





The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, England saw mainly **four COVID-19 waves**; in which the first reached the peak on April, 06, 2020, the second on November, 19, 2020, the third on July, 22, 2021, and the fourth on November, 08, 2021.

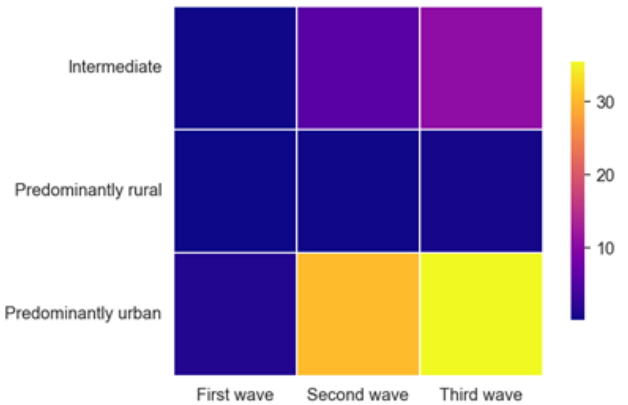
During the first wave, predominantly urban regions of England were the most affected by the virus such as Tyneside, Birmingham, Hertfordshire, Barnsley, and Sheffield. Some intermediate regions were also hit during the first wave including Oxfordshire, Worcestershire, Suffolk, and Gloucestershire.

During the second wave, the infection number of COVID-19 started to increase especially in urban regions such as reported in Birmingham, Hertfordshire, Leeds, Barnsley and Tyneside. However, the infection growth rates were less intense for intermediate regions as those reported in urban regions such as reported in Lincolnshire, Worcestershire, Oxfordshire, and Essex Haven Gateway.

During the third wave, the infections number in England continued to increase following the same regional pattern as reported in Hertfordshire, Tyneside, Staffordshire, and Birmingham.

When taking population dynamics and regional characteristics into account, we found that predominantly urban regions represent 77% of the total regions of England and host 76% of the total population, while intermediate regions represent 21% and host 22% of the total population. Predominantly rural regions represent 2% and host 1.31% of the total population of England. Therefore, urban regions are more likely to get hit by the virus considering their share of the total population and regional distribution.

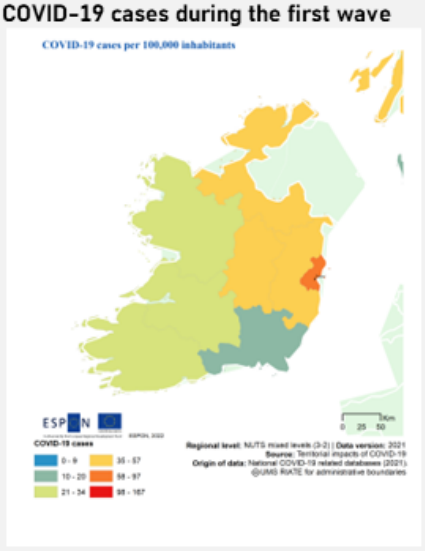
Overall, predominantly urban regions were the most hit by the virus (counting 79% of the total cases across the three waves), followed by predominantly rural regions (20%) and intermediate regions (1%). Same urban regions were experiencing intense COVID-19 cases.



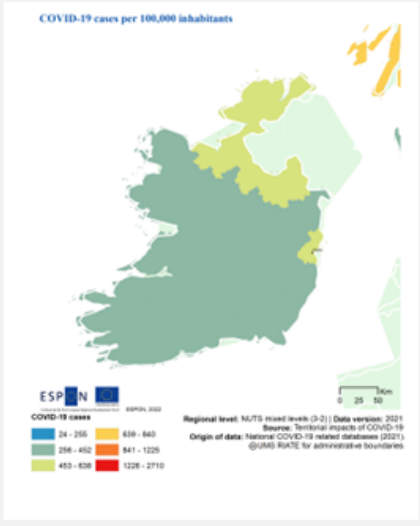
Total COVID-19 cases	England	Number of regions	Data source
22-06-2022 19M		133 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 6 - Spatial diffusion of the COVID-19 in the British Isles region (case of Ireland)

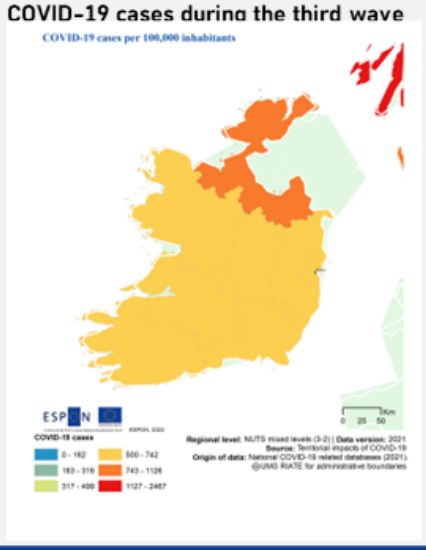
COVID-19 cases during the first wave

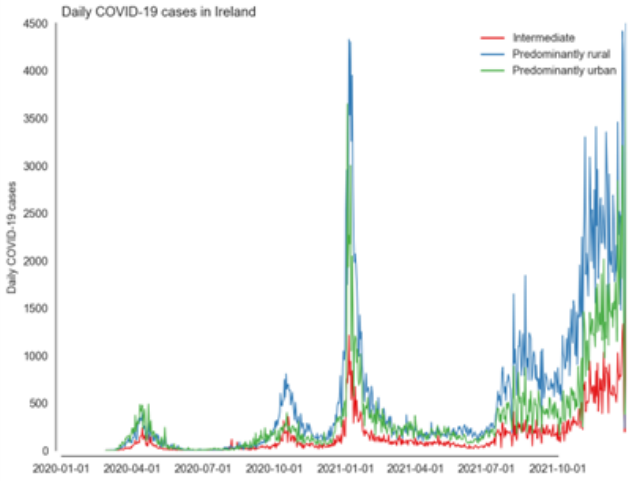


COVID-19 cases during the second wave



COVID-19 cases during the third wave





The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, Ireland saw mainly **five COVID-19 waves**; in which the first reached the peak on April, 05, 2020, the second on October, 08, 2020, the third on January, 21, 2021, the fourth on August, 13, 2021, and the fifth on November, 13, 2021.

During the first wave, both predominantly urban regions (e.g., Dublin) and predominantly rural regions (e.g., Border, South-West, and Mid-West) were hit almost with the same magnitude; however, intermediate regions were less hit by the virus compared to other types of regions (e.g., Mid-East).

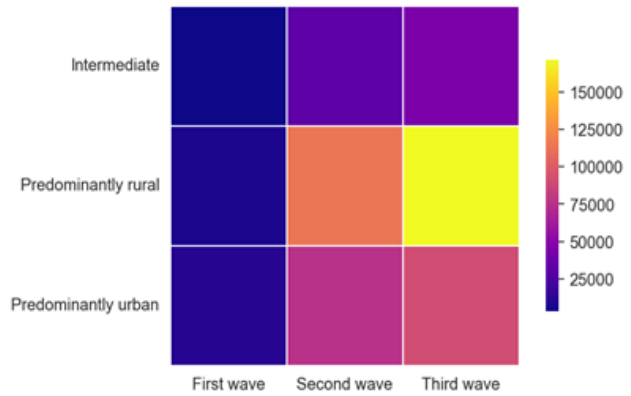
During the second wave the virus spread to all Irish regions. However, while the first wave touched severely urban regions, the second wave hit more rural regions (e.g., Border, South-West, Mid-West, and Midland).

During the third wave, and contrary to Sweden and France, the infection number in Ireland continues to increase following the same infections pattern of the second wave, meaning that rural regions (e.g., Border, South-West, and Mid-West) are still counting the highest infections numbers, followed by urban regions (e.g., Dublin).

While taking population dynamics and regional characteristics into account, we found that rural areas represent 75% of Irish regions and host 57% of the total Irish population, while intermediate regions represent 12.5% and host 15% of the total population, and urban areas represent 12.5% and host only 28% of the total population. Therefore, rural regions are more likely to get hit by the virus considering their number and share of the total Irish population.

Figure down below (the cube) shows COVID-19 cases magnitude during the three waves and disaggregated by types of regions.

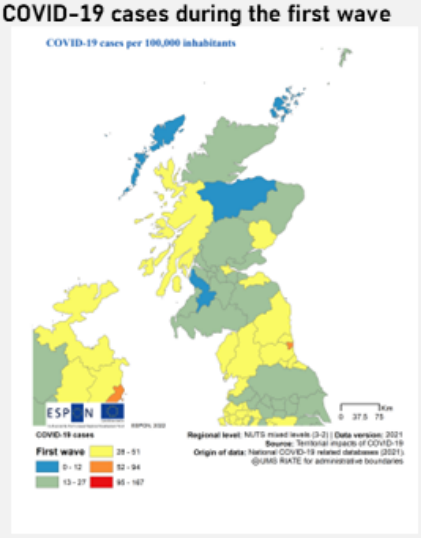
Overall, Irish predominantly rural regions were the most hit by the virus (counting 53% of the total cases), followed by predominantly urban regions (32%) and intermediate regions (14%), respectively.



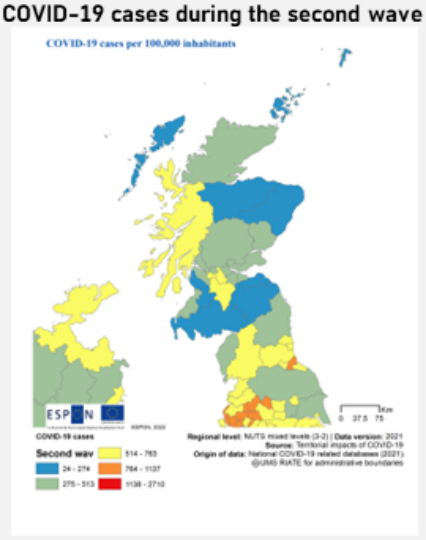
Total COVID-19 cases	Ireland	Number of regions	Data source
22-06-2022 1.58M		8 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 7 - Spatial diffusion of the COVID-19 in the British Isles region (case of Scotland)

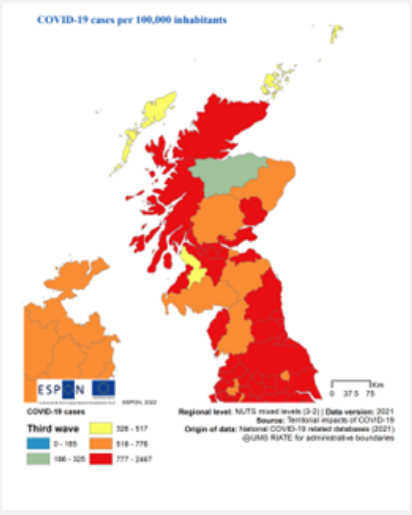
COVID-19 cases during the first wave

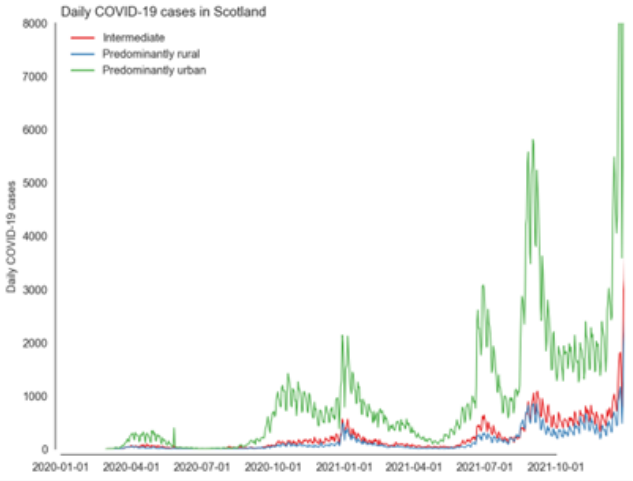


COVID-19 cases during the second wave



COVID-19 cases during the third wave





The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, Scotland saw mainly **four COVID-19 waves**; in which the first reached the peak on April, 11, 2020, the second on October, 27, 2020, the third on July, 13, 2021, and the fourth on September, 16, 2021.

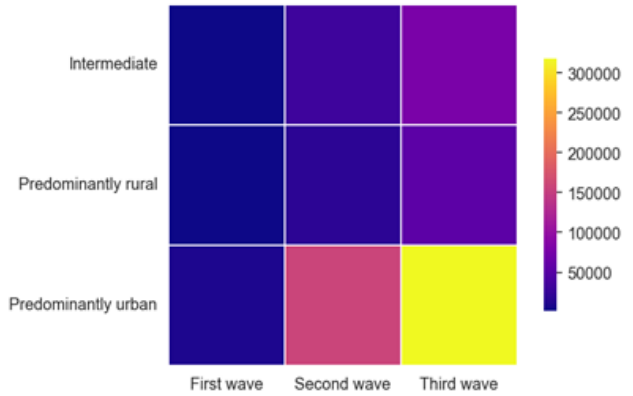
During the first wave, predominantly urban regions of Scotland were the most affected by the pandemic as reported in Glasgow, Edinburgh, Angus and Dundee, and Clackmannanshire. During the first wave a hierarchical diffusion model was triggered in Scotland whereby the urban regions were hit the first and then intermediate and rural areas.

During the second wave, the infection number of COVID-19 started to increase following the same regional pattern of the first wave as reported in Glasgow, North Lanarkshire, South Lanarkshire, and Edinburgh. However, the infection growth rates were less intense in intermediate regions including Aberdeen, East Ayrshire, and South Ayrshire.

During the third wave, the infection numbers in Scotland continued to increase following the same regional pattern of the first and the second waves.

When taking population dynamics and regional characteristics into account, we found that predominantly urban regions represent 48% of the total regions of Scotland and host 66% of the total population, while intermediate regions represent 22% and host 24% of the total population. Predominantly rural regions represent 49% but only host 10% of the total population of Scotland. Therefore, urban regions are more likely to get hit by the virus considering their share of the total population and regional distribution.

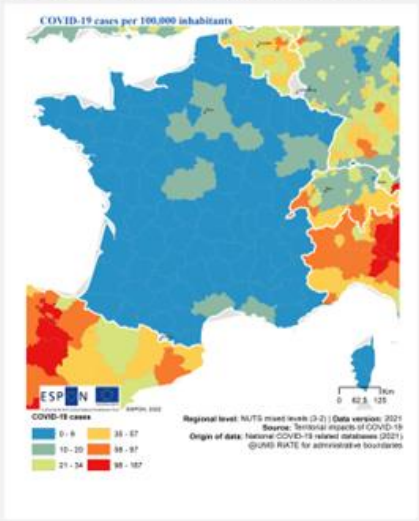
Overall, predominantly urban regions were the most hit by the virus (counting 73% of the total cases across the three waves), followed by intermediate regions (16%) and predominantly rural regions (11%). Same urban regions were experiencing intense COVID-19 cases.



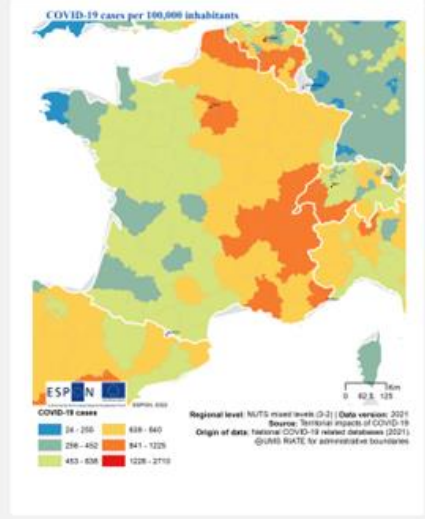
Total COVID-19 cases	Scotland	Number of regions	Data source
22-06-2022 1.98M		23 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 8 – Spatial diffusion of the COVID-19 in the Western region (case of France)

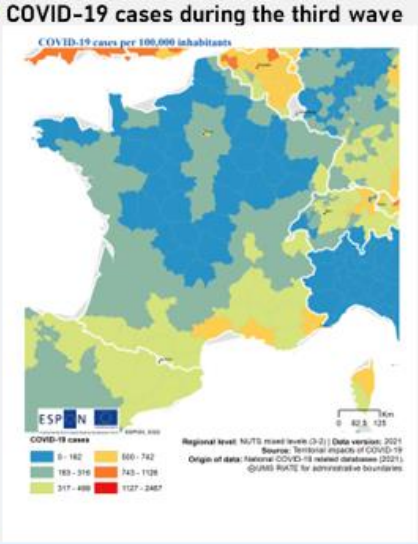
COVID-19 cases during the first wave

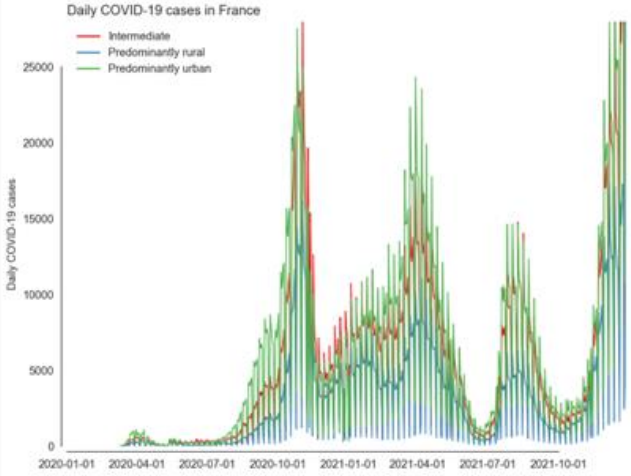


COVID-19 cases during the second wave



COVID-19 cases during the third wave





The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, France saw mainly **five COVID-19 waves**; in which the first reached the peak on April, 07, 2020, the second on November, 03, 2020, the third on April, 11, 2021, the fourth on August, 08, 2021, and the fifth on November, 28, 2021.

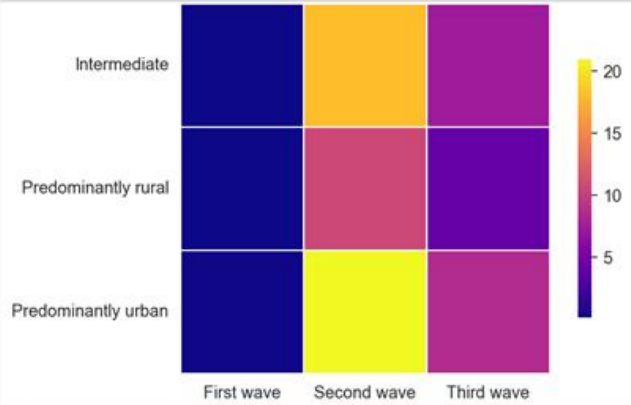
During the first wave, predominantly urban regions (e.g., Paris, Bouches du Rhône, Hauts de Seine, and Val d'Oise) were the most effected by the pandemic, followed by intermediate regions (e.g., Seine et Marne, Oise, and Hérault) counting the highest number of COVID-19 infection cases. Predominantly rural regions were less hit by the pandemic (e.g., Eure et Loir, Eure, Somme, and Aisne).

During the second wave, the infection number continues to increase following the same types of regions, meaning that urban areas are still experiencing the highest number of infection cases, followed by intermediate and rural regions.

During the third wave, the infection number in France decreases following the same infections pattern of the first and second wave, meaning that predominantly urban regions (e.g., bouche du Rhône, Paris, and Rhône) are still experiencing the highest COVID-19 infection cases compared to intermediate and predominantly rural regions.

When taking population dynamics and regional characteristics into account, we found that rural areas represent 55% of the French regions and host 29% of the total French population, while intermediate regions represent 30% and host 36% of the total population, and urban regions represent 15% and host 35% of the total population. Therefore, urban and intermediate regions are more likely to get hit by the virus considering their number and share of the total French population.

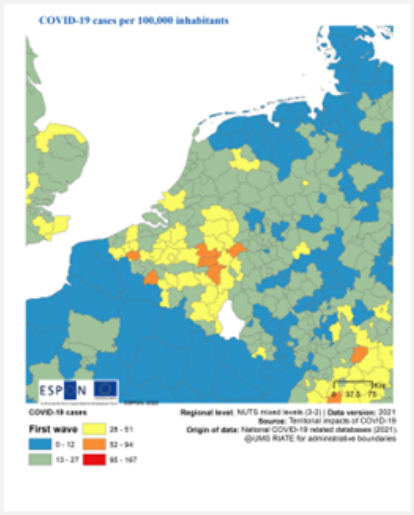
Overall, French urban regions were the most hit by the virus (counting 43% of the total cases), followed by intermediate regions (35%) and predominantly rural regions (22%), respectively.



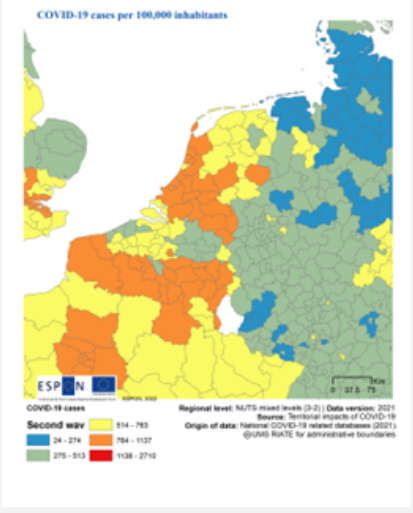
Total COVID-19 cases	France	Number of regions	Data source
22-06-2022 29.4M		96 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 9 – Spatial diffusion of the COVID-19 in the Western region (case of Belgium)

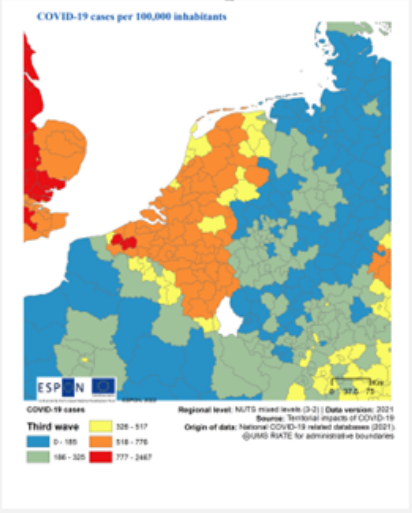
COVID-19 cases during the first wave

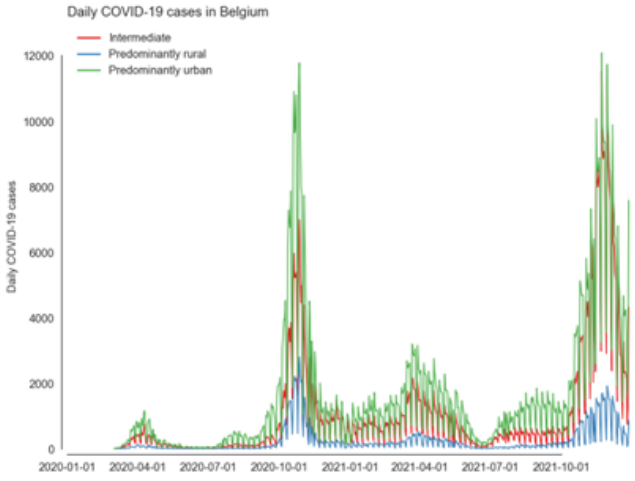


COVID-19 cases during the second wave



COVID-19 cases during the third wave





During the study timeframe, Belgium saw mainly **four COVID-19 waves**; in which the first reached the peak on April, 07, 2020, the second on October, 29, 2020, the third on March, 27, 2021, and the fourth on December, 21, 2021.

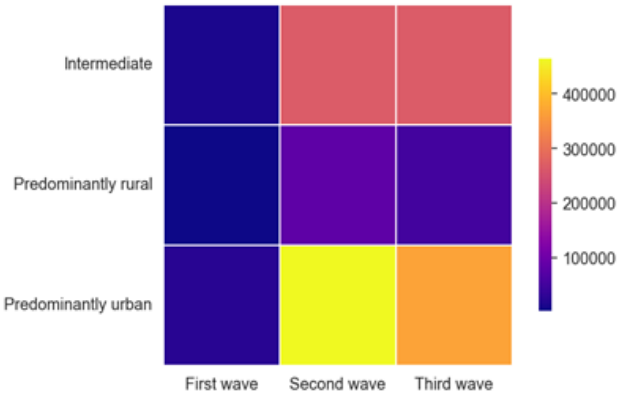
During the first wave, predominantly urban regions of Belgium were the most affected by the pandemic as reported in Bruxelles-Capitale, Liège, Antwerpen, and Hasselt. During the first wave a hierarchical diffusion model was triggered in Belgium whereby the urban regions were hit the first and then intermediate and rural areas.

During the second wave, the infection number of COVID-19 started to increase following the same regional pattern of the first wave (urban and intermediate regions) as reported during the first wave. However, the infection growth rates were less intense in intermediate regions including the regions of Gent, Namur, Nivelles, and Turnhout.

During the third wave, and following the same hierarchical diffusion spotted during the first and second wave, the infection numbers in Belgium continued to increase in predominantly urban regions (e.g., the regions of Bruxelles, Antwerpen, and Halle-Vilvoorde).

When taking population dynamics and regional characteristics into account, we found that predominantly urban regions represent 29% of the total regions and host 53% of the total population, while intermediate regions represent 44% and host 36% of the total population. Predominantly rural regions represent 27% but only host 8% of the total population of Belgium. Therefore, urban regions are more likely to get hit by the virus considering their share of the total population and regional distribution.

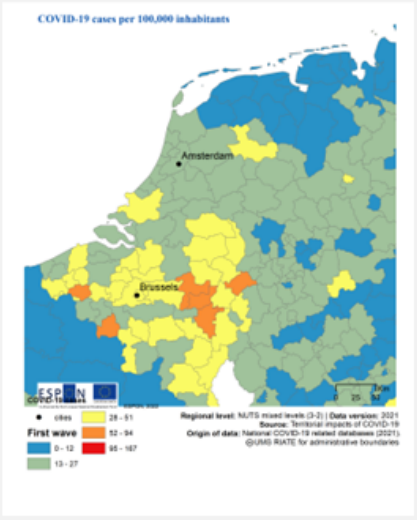
Overall, predominantly urban regions were the most hit by the virus (counting 56% of the total cases across the three waves), followed by intermediate regions (36%) and predominantly rural regions (8%). Same urban regions were experiencing intense COVID-19 cases.



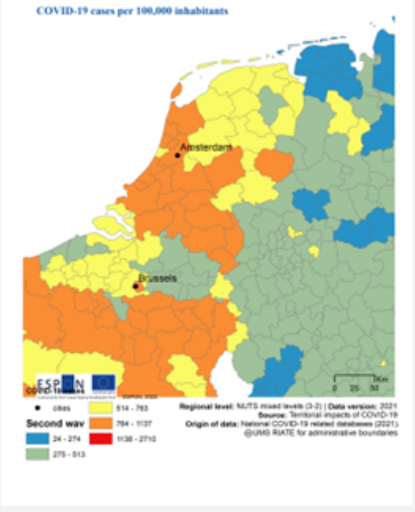
Total COVID-19 cases	Belgium	Number of regions	Data source
22-06-2022 4.2M		44 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 10 – Spatial diffusion of the COVID-19 in the Western region (case of the Netherlands)

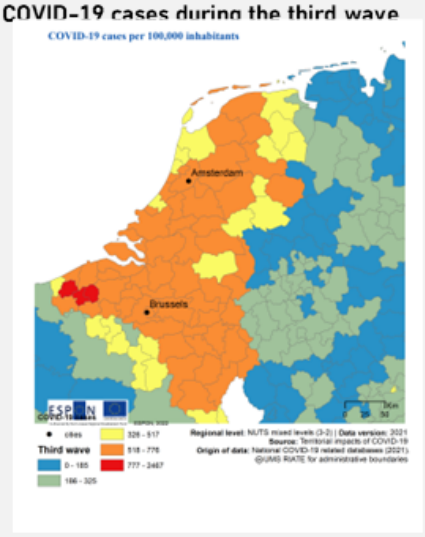
COVID-19 cases during the first wave

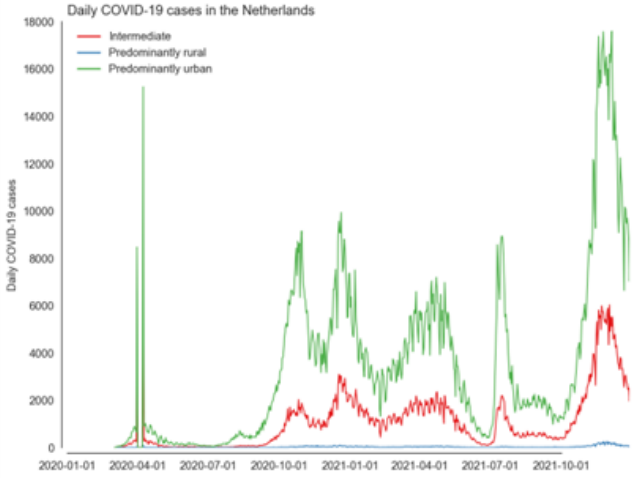


COVID-19 cases during the second wave



COVID-19 cases during the third wave





During the study timeframe, the Netherlands saw mainly **six COVID-19 waves**; in which the first reached the peak on March, 26, 2020, the second on November, 14, 2020, the third on December, 28, 2020, the fourth on April, 17, 2021, the fifth on July, 07, 2021, and the sixth on December, 27, 2021.

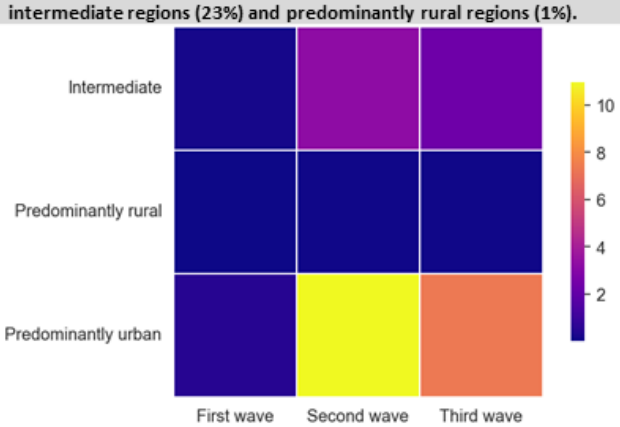
During the first wave, predominantly urban regions of the Netherlands were the most affected by the pandemic as reported in Groot-Rijnmond, Groot-Amsterdam, Utrecht, and Gravenhage. During the first wave a hierarchical diffusion model was triggered in the Netherlands whereby the urban regions were hit the first and then intermediate and rural areas.

During the second wave, the infection number of COVID-19 started to increase following the same regional pattern of the first wave (urban and intermediate regions) as reported during the first wave. However, the infection growth rates were less intense in intermediate regions including the regions of Noordoost-Noord-Brabant, and Achterhoek.

During the third wave, and following the same hierarchical diffusion of the first and second wave, the infection numbers in the Netherlands continued to increase in predominantly urban regions (e.g., the regions of Groot-Rijnmond, Groot-Amsterdam, Utrecht).

Taking account the local regional characteristics, we found that predominantly urban regions represent 55% of the total regions and host 74% of the total population, while intermediate regions represent 42% and host 25% of the total population. Predominantly rural regions represent 3% but only host 0.60% of the total population the Netherlands. Therefore, urban regions are more likely to get hit by the virus considering their share of the total population and regional distribution.

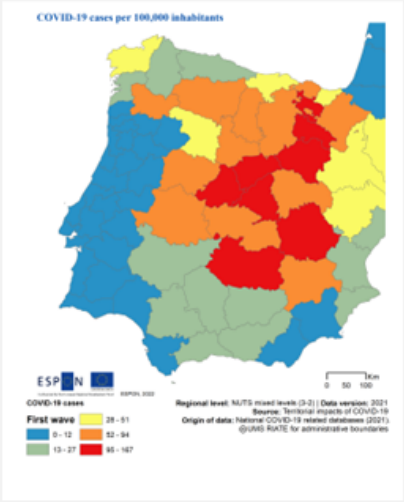
Overall, predominantly urban regions were the most hit by the virus (counting 76% of the total cases across the three waves), followed by intermediate regions (23%) and predominantly rural regions (1%).



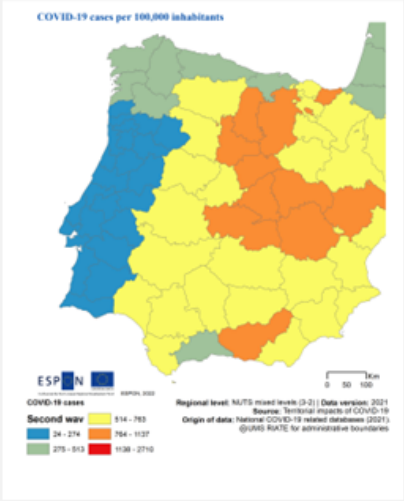
Total COVID-19 cases	Netherlands	Number of regions	Data source
22-06-2022 8.14M		40 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 11 – Spatial diffusion of the COVID-19 in the Southern region (case of Portugal)

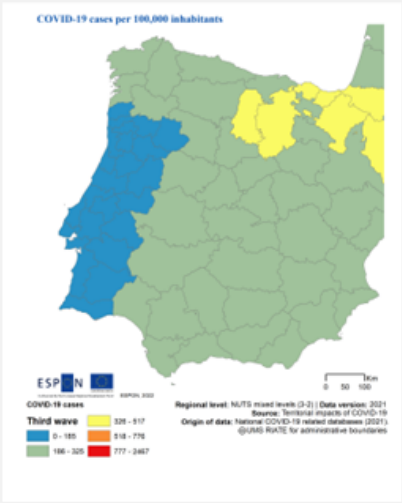
COVID-19 cases during the first wave

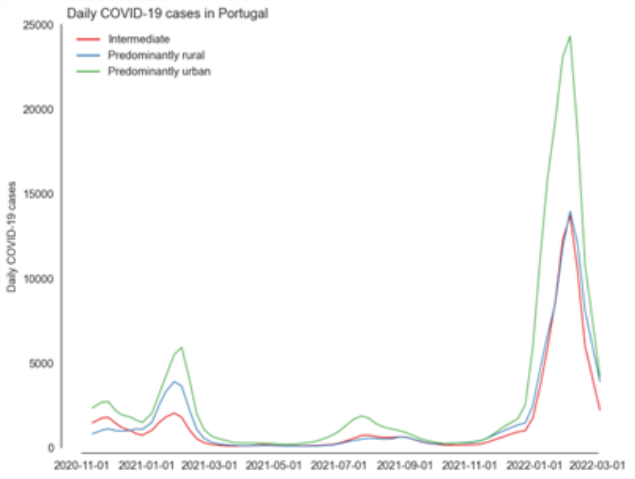


COVID-19 cases during the second wave



COVID-19 cases during the third wave





The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, Portugal saw mainly **three COVID-19 waves**; in which the first reached the peak on December, 18, 2020, the second on March, 18, 2021, and the third on July, 22, 2021.

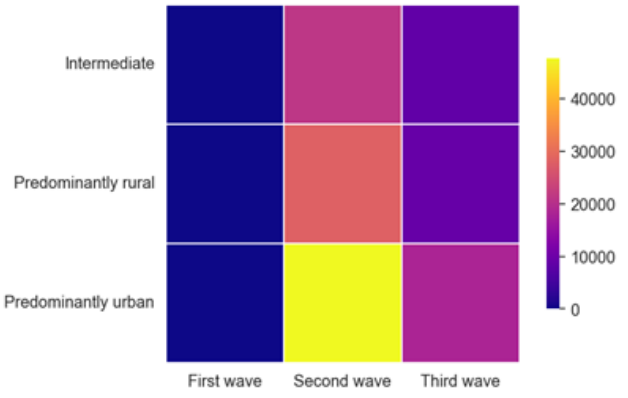
During the first wave, as outlined at the European scale, data were not available for Portugal; therefore, we could not inspect the spatial diffusion of the virus across regions of Portugal.

During the second wave, the infection number of COVID-19 started to be recorded at the subregional level (NUTS3). Where Predominantly urban areas were the most effected by the virus, and witnessed a higher COVID-19 infections cases such as reported in the metropolitan area of Lisboa, and Porto ranking the two first regions with the highest COVID-19 cases, followed by the three intermediate regions of Ave, Cavado, and Tâmega e Sousa, respectively.

During the third wave, the infection number in Portugal decreases considerably especially for predominantly rural regions. The overall pattern of regional cases still maintains the same ranking with the metropolitan area of Liboa, and Porto counting the highest values.

When taking population dynamics and regional characteristics into account, we found that predominantly rural regions represent 64% of the total regions of Portugal and host 31% of the total Portuguese population, while intermediate regions represent 24% and host 22% of the total population; However, while urban regions represent only 12%, they host the highest share of the total population (47%). Therefore, urban regions are more likely to get hit by the virus considering their share of the total Portuguese population.

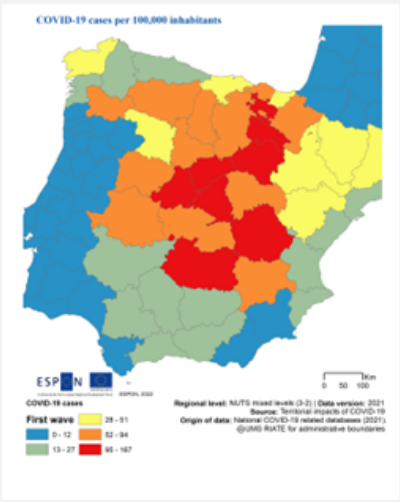
Overall, predominantly urban Portuguese regions were the most hit by the virus (counting 50% of the total cases across the three waves), followed by predominantly rural regions (30%) and intermediate regions (20%).



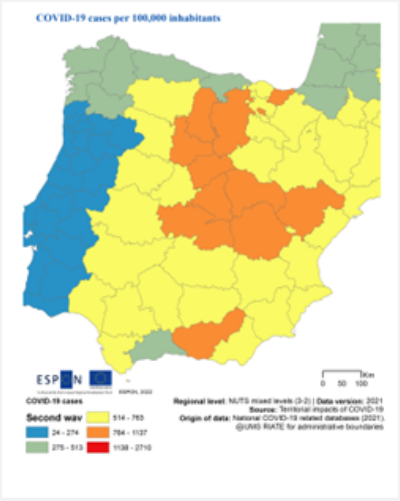
Total COVID-19 cases		Number of regions	Data source
22-06-2022 5.08M	**Portugal**	25 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 12 – Spatial diffusion of the COVID-19 in the Southern region (case of Spain)

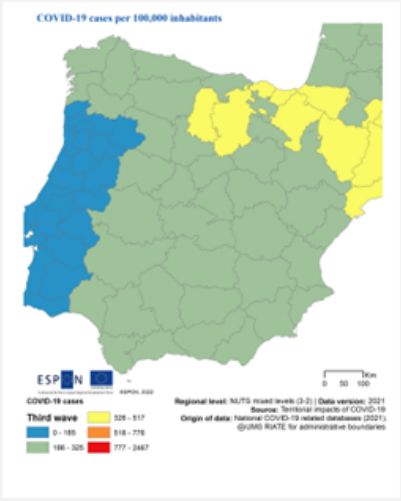
COVID-19 cases during the first wave

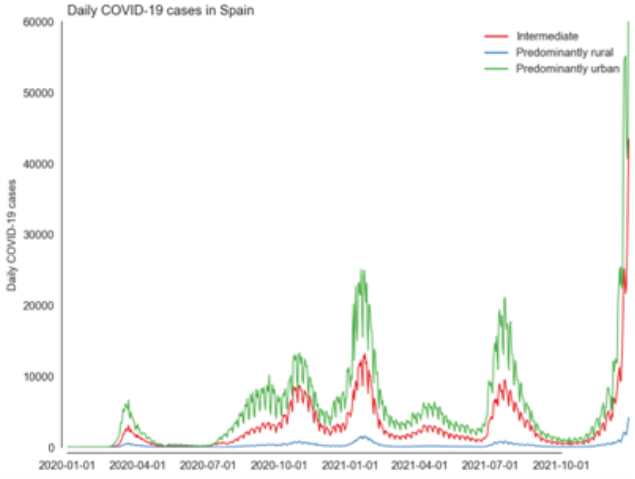


COVID-19 cases during the second wave



COVID-19 cases during the third wave





The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, Spain saw mainly **five COVID-19 waves**; in which the first reached the peak on April, 18, 2020, the second on November, 11, 2020, the third in June, 06, 2021, the fourth in August, 21, 2021, and the fifth in October, 27, 2021.

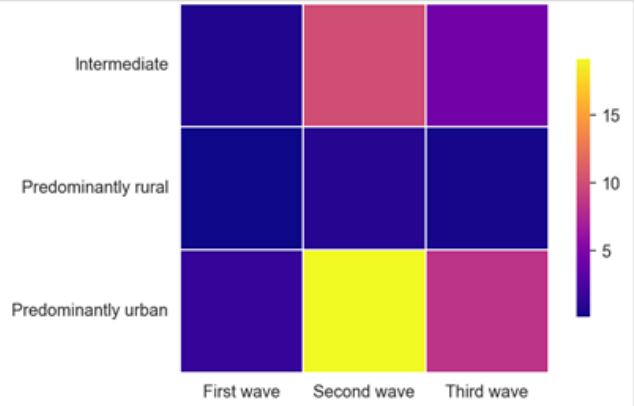
During the first wave, urban regions were the most affected by the virus such as the region of Madrid, Barcelona, Bizkaia, and Valencia counting the highest COIVD-19 cases.

During the second wave, Spain seen an increased number of cases following the same regional pattern, where predominantly urban areas were the most affected but also other urban areas became new centres of the pandemic including Alicante, Sevilla, Murcia, and Malaga.

During the third wave, the infection number in Spain continues to increase considerably especially for previously hit urban areas, and with each wave, new urban regions emerge as a cluster of the pandemic such as the case of Gipuzkoa, Zaragoza, and Cadiz. With less magnitude –compared to urban regions- intermediate regions also seeing a considerable increase in COVID-19 cases.

When taking population dynamics and regional characteristics into account, we found that intermediate regions represent 55% of the total Spanish regions, but host only 33% of the total Spanish population, while urban regions represent 29%, but host the highest shares of the total population estimated to 63%. Therefore, urban regions are more likely to get hit by the virus considering their share of the total Spanish population.

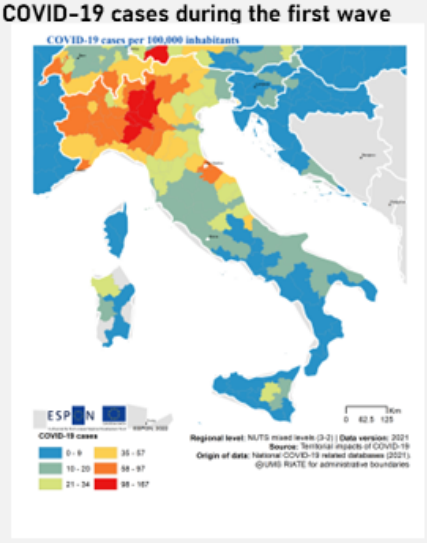
Overall, predominantly urban regions of Spain were the most hit by the virus (counting 64% of the total cases across the three waves), followed by intermediate regions (33%) and predominantly rural regions (3%). Rural regions were less hit by the virus, this may explained by the weak regional connectivity.



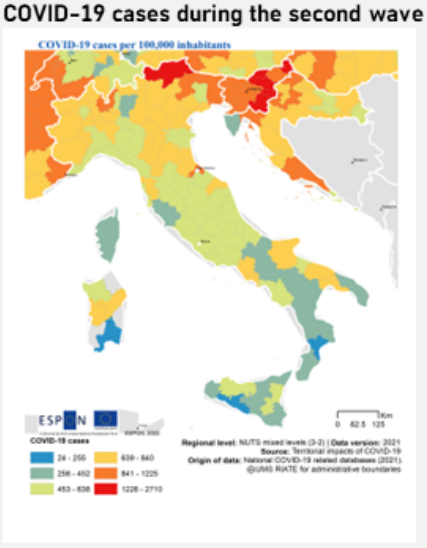
Total COVID-19 cases		Number of regions	Data source
22-06-2022 12.6M	**Spain**	51 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 13 – Spatial diffusion of the COVID-19 in the Southern region (case of Italy)

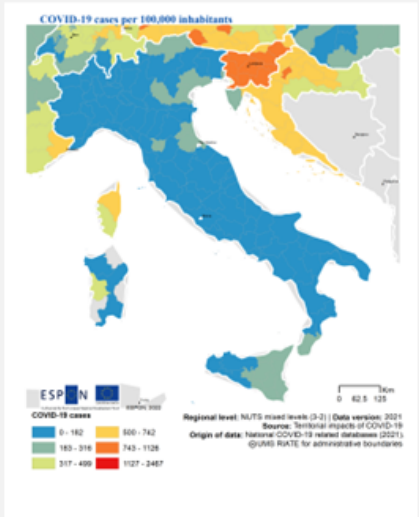
COVID-19 cases during the first wave

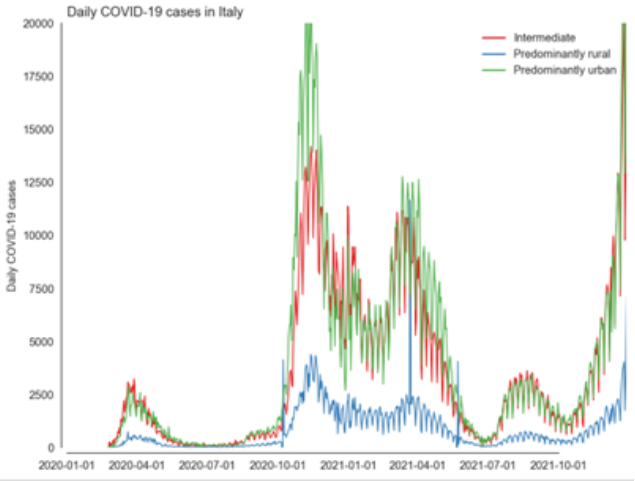


COVID-19 cases during the second wave



COVID-19 cases during the third wave





The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, Italy saw mainly **five COVID-19 waves**; in which the first reached the peak on March, 25, 2020, the second on October, 16, 2020, the third on March, 04, 2021, the fourth on August, 19, 2021, and the fifth on November, 23, 2021.

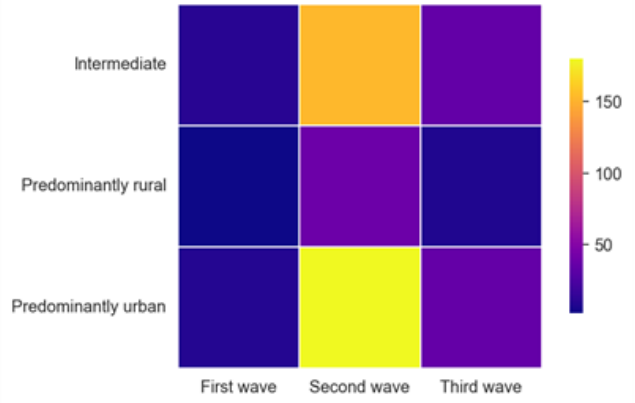
During the first wave, predominantly urban regions (e.g., Milano, Torino, and Bergamo) were the most affected by the pandemic, followed by intermediate regions (e.g., Brescia, Cremona, and Verona) counting the highest number of COVID-19 infection cases. Predominantly rural regions were less hit by the pandemic (e.g., Alessandria, Mantova, Bolzano-Bozen, and Cuneo).

During the second wave, the infection number continues to increase in all of the Italian regions following the same typological pattern, meaning that urban areas are still experiencing the highest number of infection cases, followed by intermediate and rural regions.

During the third wave, the infection number in Italy decreases significantly, both predominantly urban (e.g., Roma, Napoli, and Milano) and intermediate regions (e.g., Padova, Treviso, Verona, and Bologna) were experiencing the same COVID-19 infection cases magnitude.

When taking population dynamics and regional characteristics into account, we found that intermediate regions represent 54% of the total Italian regions and host 42% of the total Italian population, while urban regions represent 28% and host 50% of the total population, and rural regions represent 18% and host 10% of the total population. Therefore, urban and intermediate regions are more likely to get hit by the virus considering their number and share of the total Italian population.

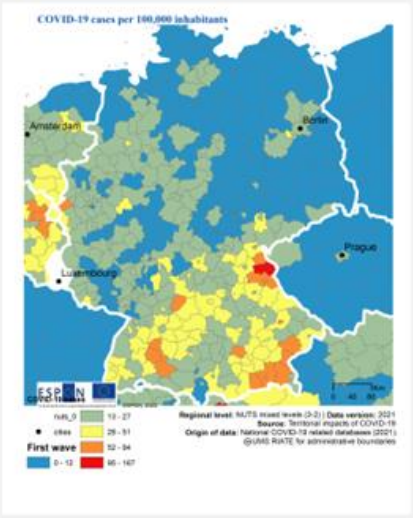
Overall, Italian urban regions were the most hit by the virus (counting 48% of the total cases), followed by intermediate regions (42%) and predominantly rural regions (10%), respectively.



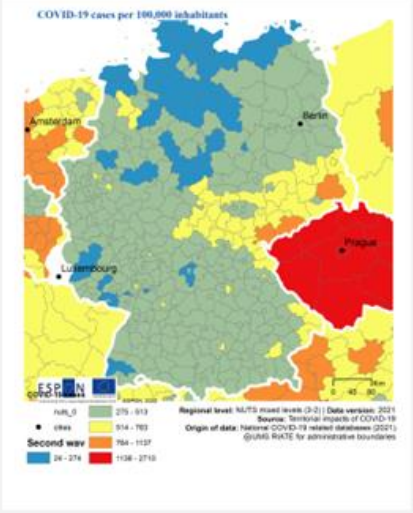
Total COVID-19 cases		Number of regions	Data source
22-06-2022 18M	**Italy**	106 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 14 – Spatial diffusion of the COVID-19 in the West-Central region (case of Germany)

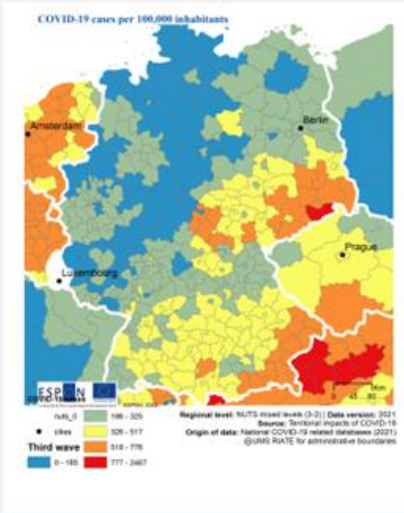
COVID-19 cases during the first wave

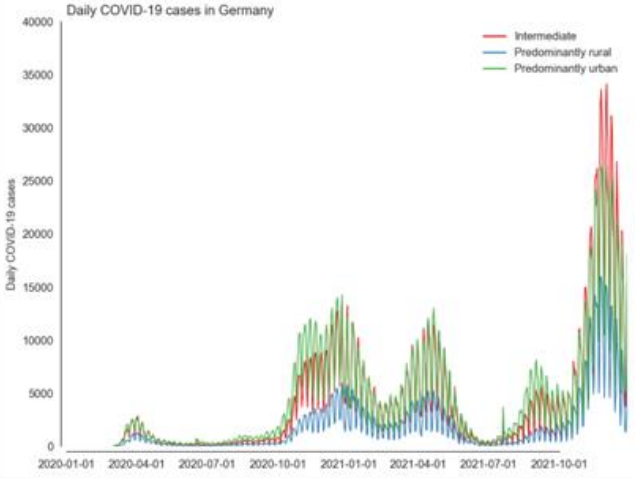


COVID-19 cases during the second wave



COVID-19 cases during the third wave





During the study timeframe, Germany has known mainly **four COVID-19 waves**; in which the first reached the peak on March, 26, 2020, the second on December, 17, 2020, the third on April, 03, 2021, and the fourth on December, 19, 2021.

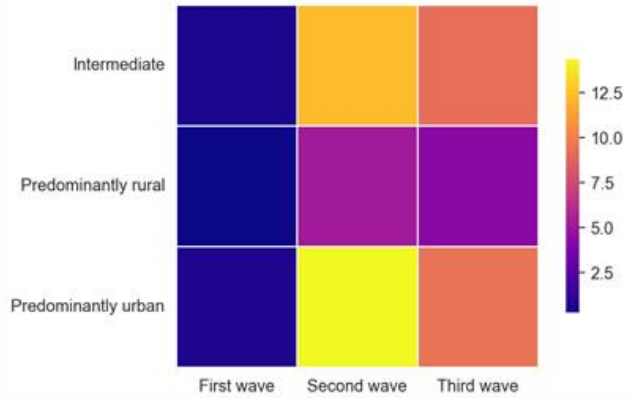
During the first wave, predominantly urban regions of Germany were the most affected by the pandemic as reported in Berlin, München, and Hamburg. During the first wave a hierarchical diffusion model was triggered in Germany whereby the urban regions were hit the first and then intermediate (Rosenheim, Landkreis) and rural areas.

During the second wave, the infection number of COVID-19 started to increase following the same regional pattern of the first wave (urban and intermediate regions) as reported during the first wave. However, the infection growth rates started escalating in intermediate regions as reported in Erzgebirgskreis, Zwickau, Mittelsachsen, and Main-Kinzig-Kreis.

During the third wave, and following the same hierarchical diffusion spotted during the first and second wave, the infection numbers in Germany decrease, especially in predominantly urban regions (e.g., the regions of Berlin, München, and Hamburg).

When taking population dynamics and regional characteristics into account, we found that predominantly urban regions represent 24% of the total regions and host 44% of the total population, while intermediate regions represent 49% and host 41% of the total population. Predominantly rural regions represent 27% but only host 17% of the total population of Germany. Therefore, urban and intermediate regions are more likely to get hit by the virus considering their share of the total population and regional distribution.

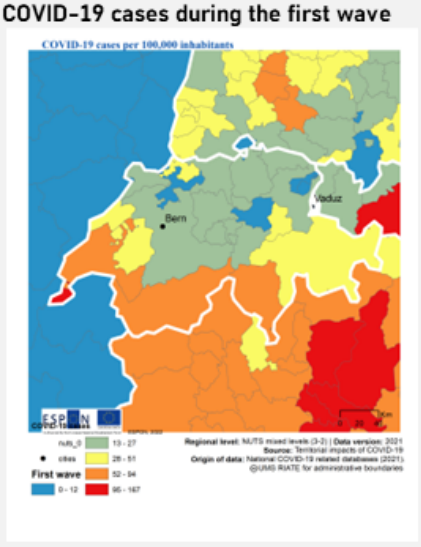
Overall, predominantly urban regions were the most hit by the virus (counting 43% of the total cases across the three waves), followed by intermediate regions (39%) and predominantly rural regions (17%).



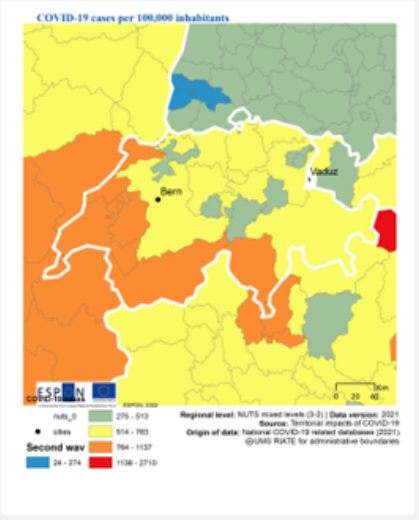
Total COVID-19 cases		Number of regions	Data source
22-06-2022 27.5M	**Germany**	401 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 15 – Spatial diffusion of the COVID-19 in the West-Central region (case of Switzerland)

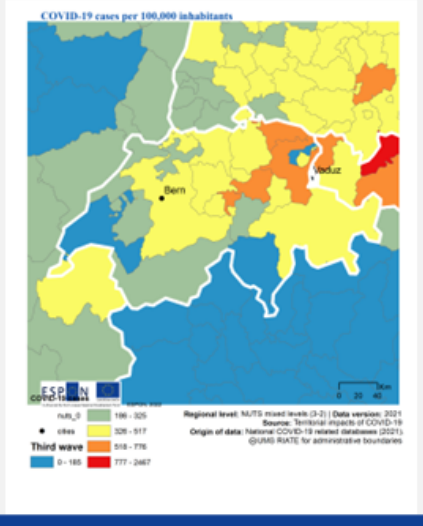
COVID-19 cases during the first wave

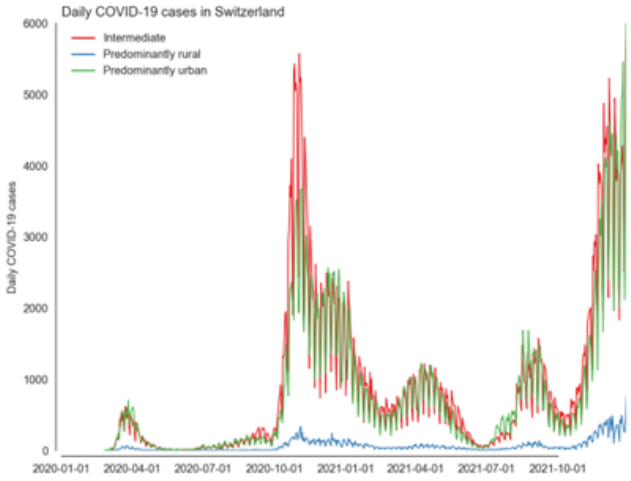


COVID-19 cases during the second wave



COVID-19 cases during the third wave





During the study timeframe, Switzerland saw mainly **five COVID-19 waves**; in which the first reached the peak on March, 24, 2020, the second on November, 19, 2020, the third on April, 13, 2021, the fourth on August, 27, 2021, and the fifth on December 15, 2021.

During the first wave, both intermediate and predominantly urban regions of Switzerland were the most affected by the pandemic as reported in Vaud (intermediate region) accounting the highest value of COVID-19 infection numbers, followed by the urban regions of Genève, Zürich, and Ticino.

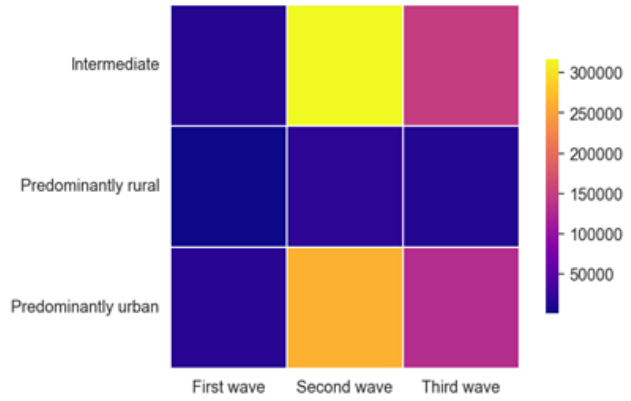
During the second wave, the infection numbers of COVID-19 started to increase for intermediate regions such as in Vaud, Bern, and St. Gallen, and with less intense magnitude in urban regions such as reported in Zürich, Aargau, and Genève.

During the third wave, and following the same hierarchical diffusion spotted during the first and second wave, the infection numbers continued to increase in Zürich, Genève, and Aargau. During the three waves, predominantly rural regions were less hit by the virus.

During the third wave, COVID-19 cases decreases across all regions.

When taking population dynamics and regional characteristics into account, we found that predominantly urban regions represent 31% of the total regions and host 46% of the total population, while intermediate regions represent 62% and host 51% of the total population in Switzerland. Predominantly rural regions represent 8% but only host 3% of the total population of Switzerland. Therefore, intermediate regions are more likely to get hit by the virus considering their share of the total population and regional distribution.

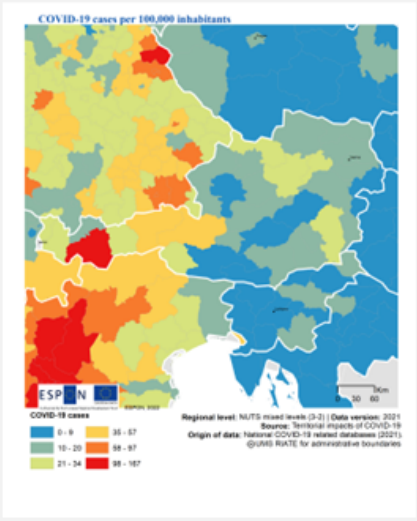
Overall, intermediate regions were the most hit by the virus (counting 52% of the total cases across the three waves), followed by predominantly urban regions (44%) and predominantly rural regions (3%).



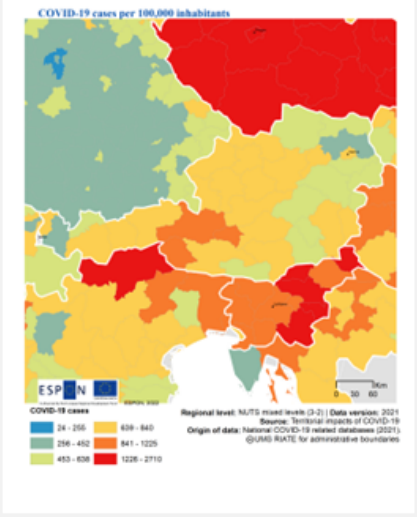
Total COVID-19 cases	Switzerland	Number of regions	Data source
22-06-2022 3.73M		26 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 16 – Spatial diffusion of the COVID-19 in the West-Central region (case of Austria)

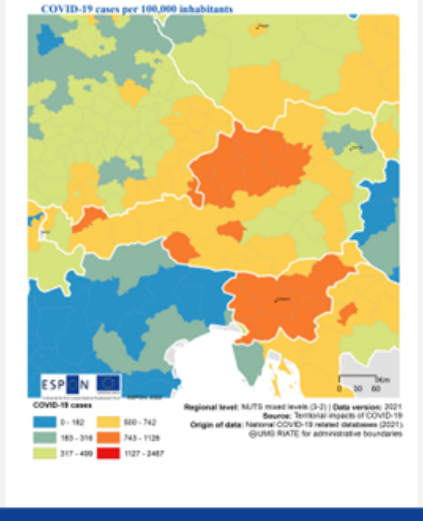
COVID-19 cases during the first wave

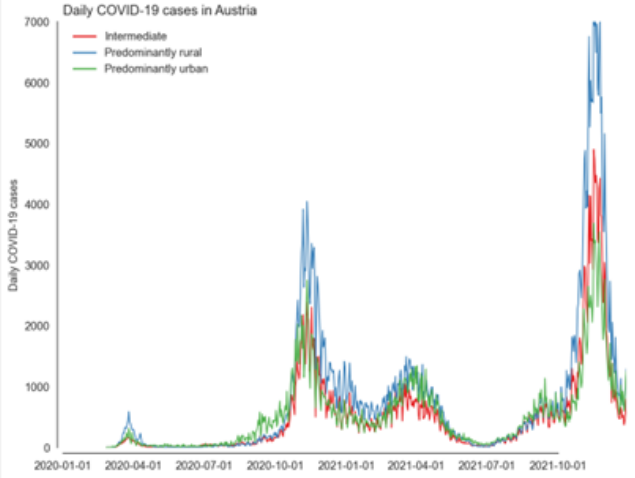


COVID-19 cases during the second wave



COVID-19 cases during the third wave





The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, Austria saw mainly **four COVID-19 waves**; in which the first reached the peak on March, 26, 2020, the second on November, 23, 2020, the third on March, 24, 2021, and the fourth on December, 04, 2021.

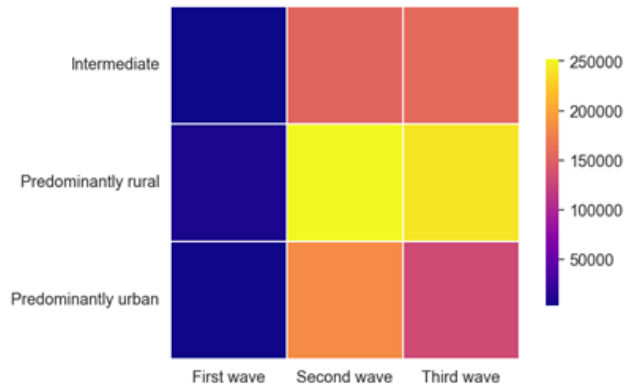
During the first wave, in total, predominantly rural regions (e.g., Tiroler Unterland, Tiroler Oberland, and Pinzgau-Pongau) were the most affected by the pandemic, followed by urban regions (e.g., Wien, Innsbruck, and Rheintal Bodenseegebiet) counting the highest number of COVID-19 infection cases. Predominantly rural regions were less hit by the pandemic compared to urban and intermediate regions.

During the second wave, the infection number continues to grow and propagate into all of the Austrian regions following the same typological pattern, meaning that rural areas are still experiencing the highest number of infection cases in total, followed closely by urban and intermediate regions.

During the third wave, the infection number stagnates for rural regions (e.g., Innviertel), increase for intermediate regions (e.g., Linz-Wels), and decrease for urban regions (e.g., Wien, Innsbruck).

When taking population dynamics and regional characteristics into account, we found that rural regions represent 67% of the total Austrian regions and host 40% of the total Austrian population, while intermediate regions represent 20% and host 28% of the total population, and urban regions represent 11% and host 32% of the total population. Therefore, rural and intermediate regions are more likely to get hit by the virus considering their number and share of the total Austrian population.

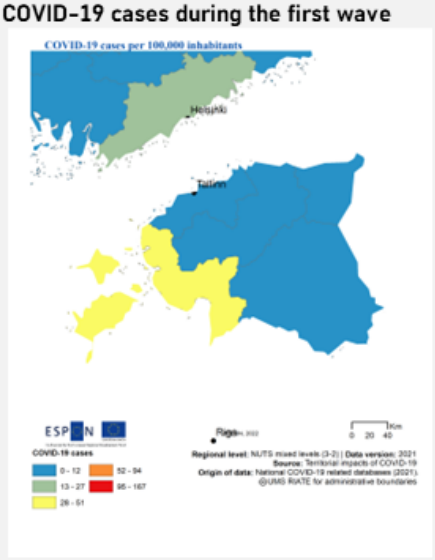
Overall, Austrian rural regions were the most hit by the virus (counting 44% of the total cases), followed simultaneously by urban regions (28%) and intermediate regions (28%).



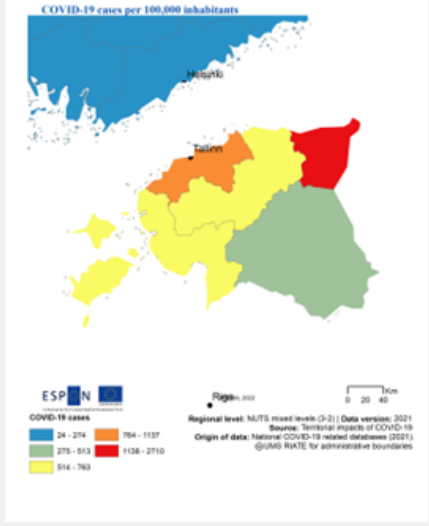
Total COVID-19 cases	Austria	Number of regions	Data source
22-06-2022 4.37M		35 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 17 – Spatial diffusion of the COVID-19 in the East-Central region (case of Estonia)

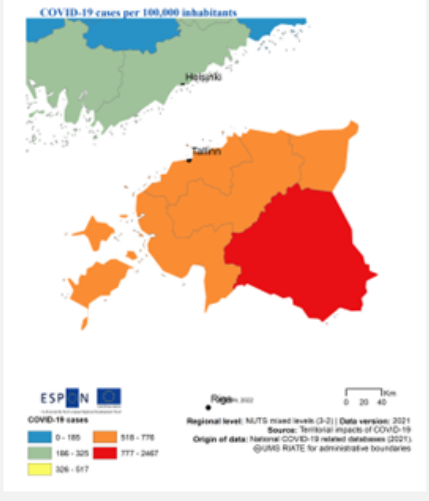
COVID-19 cases during the first wave

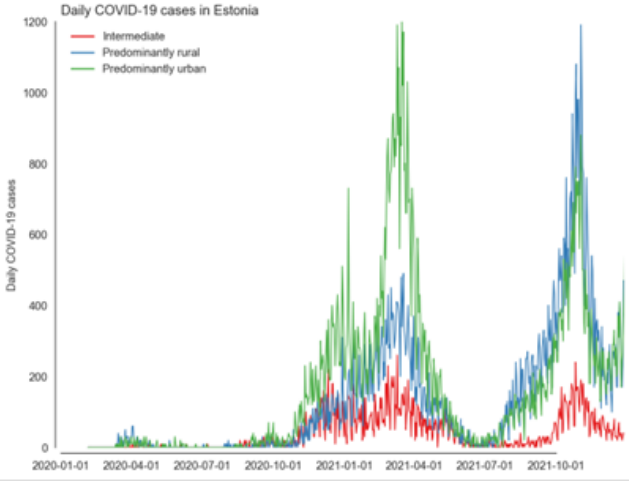


COVID-19 cases during the second wave



COVID-19 cases during the third wave





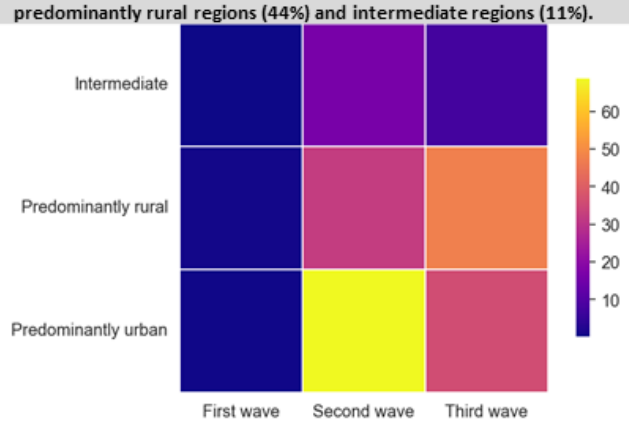
The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, Estonia saw mainly **three COVID-19 waves**; in which the first reached the peak on March, 28, 2020, the second on March, 11, 2021, and the third on November, 21, 2021.

During the first wave, the region of Lääne-Eesti (predominantly rural region) accounted for the highest COVID-19 cases, followed by the urban region of Põhja-Eesti, and then the predominantly rural region of Lõuna-Eesti. During the second wave, COVID-19 cases increased across all region, espacially for predominantly urbain regions such as Põhja-Eesti, and intermediate regions such as Kirde-Eesti. On the other hand, predominantly rural areas recorded lower values than urban and intermediate regions.

During the third wave, the overall number of COVID-19 cases has increased all regions. Nevertheless, Estonia started to experience a shifted pattern in which rural areas started to record higher COVID-19 cases such as reported in the regions of Lõuna-Eesti, Lääne-Eesti, and Kesk-Eesti. Overall, intermediate regions have seen a decrease in COVID-19 cases as reported by the region of Kirde-Eesti.

When taking population dynamics and regional characteristics into account, we found that Predominantly rural regions represent 60% of the total regions and host 44% of the total population, while predominantly urban regions represent 20% and host 46% of the total population of Estonia. Intermediate regions represent 20% but only host 10% of the total population of Estonia. Therefore, predominantly urban and rural regions are more likely to get hit by the virus considering their share of the total population and regional distribution.

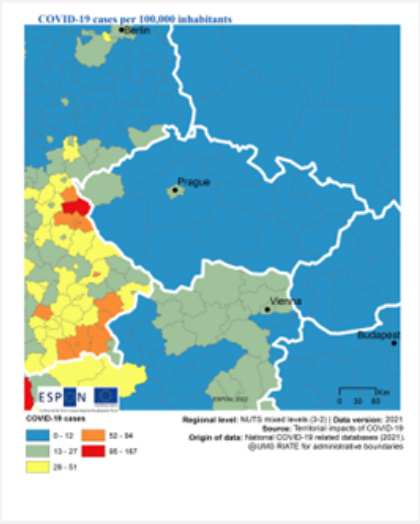
Overall, predominantly urban regions were the most hit by the virus (counting 50% of the total cases across the three waves), followed by predominantly rural regions (44%) and intermediate regions (11%).



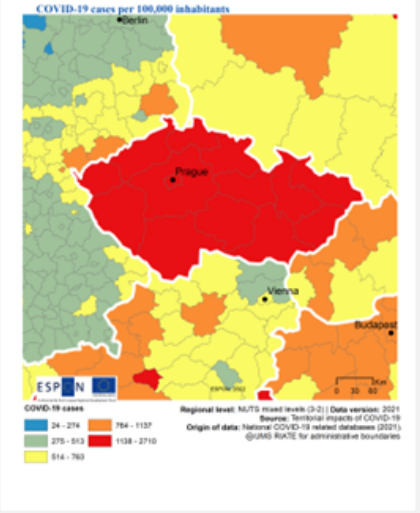
Total COVID-19 cases	Estonia	Number of regions	Data source
22-06-2022 579K		5 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 18 – Spatial diffusion of the COVID-19 in the East-Central region (case of the Czech Republic)

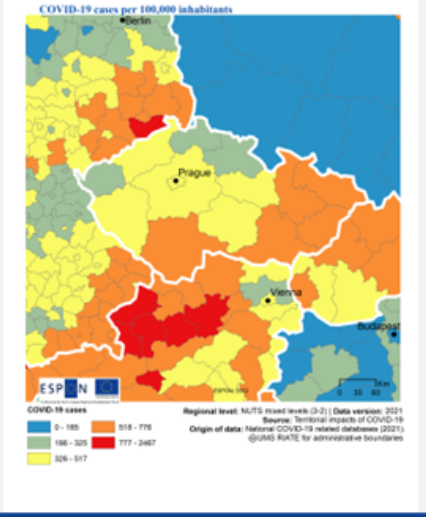
COVID-19 cases during the first wave

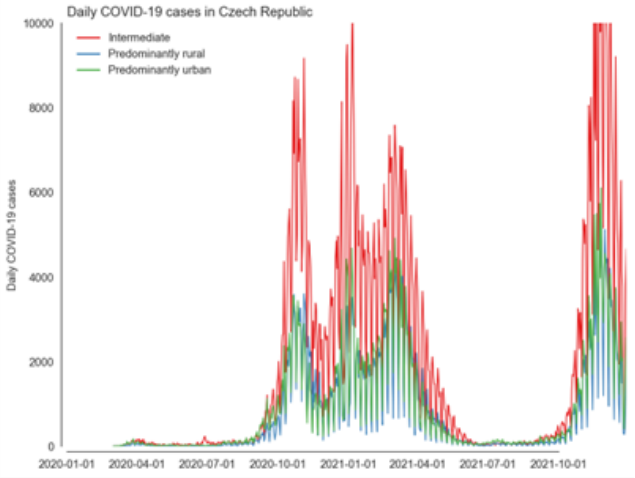


COVID-19 cases during the second wave



COVID-19 cases during the third wave





During the study timeframe, Czech Republic saw mainly **five COVID-19 waves**; in which the first reached the peak on March, 27, 2020, the second on October, 28, 2020, the third on December, 27, 2020, the fourth on March, 18, 2021, and the fifth on December, 23, 2021.

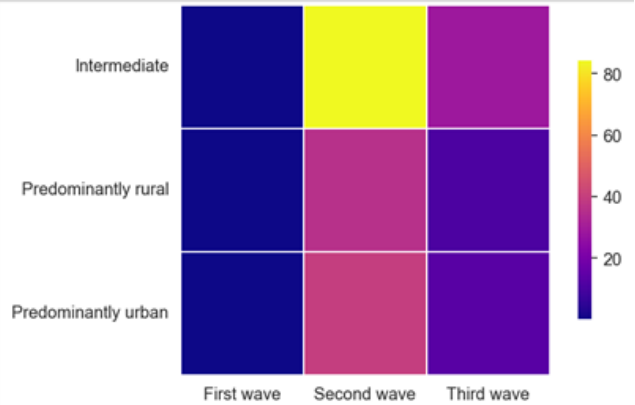
During the first wave, the region of Hlavní město Praha (Predominantly urban region) accounted for the highest number of infections cases, followed by Moravskoslezský (Intermediate region) by urban region of Středočeský kraj, and then by the intermediate region of Středočeský kraj.

During the second wave, the infection number of COVID-19 started to increase in intermediate regions (e.g., Moravskoslezský kraj, Jihomoravský kraj, Ústecký kraj, and Královéhradecký kraj) but also for urban regions (e.g., Středočeský kraj, and Hlavní město Praha), and predominatly rural areas (e.g., Jihočeský kraj, Plzeňský kraj, Pardubický kraj).

During the third wave, COVID-19 cases decreases across all regions, espacially for intermedaite regions such as in Moravskoslezský kraj, and Jihomoravský kraj but also for predominantly urban regions such as in Hlavní město Praha, and Středočeský kraj.

When taking population dynamics and regional characteristics into account, we found that intermediate regions represent 57% of the total regions and host 54% of the total population, while predominantly rural regions represent 28% and host 21% of the total population of Czechia. Predominantly urban regions represent 14% but only host 25% of the total population of Czechia. Therefore, intermediate and predominantly urban regions are more likely to get hit by the virus considering their share of the total population and regional distribution.

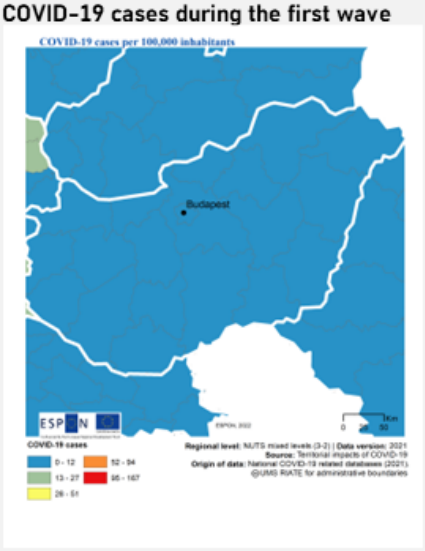
Overall, intermediate regions were the most hit by the virus (counting 53% of the total cases across the three waves), followed by predominantly urban regions (25%) and rural regions (21%).



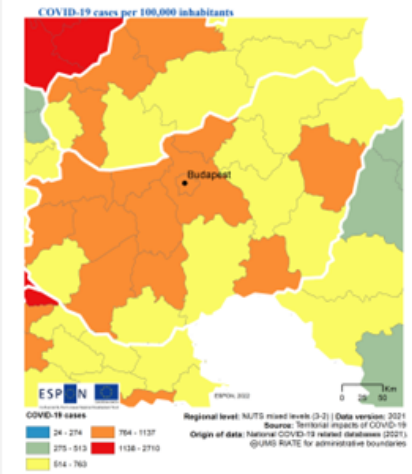
Total COVID-19 cases	Czech Republic	Number of regions	Data source
22-06-2022 3.93M		15 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 19 – Spatial diffusion of the COVID-19 in the East-Central region (case of Hungary)

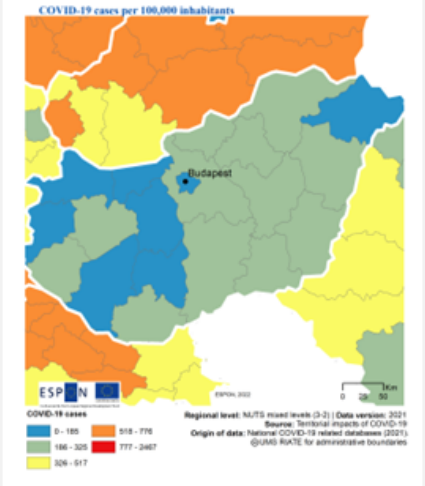
COVID-19 cases during the first wave

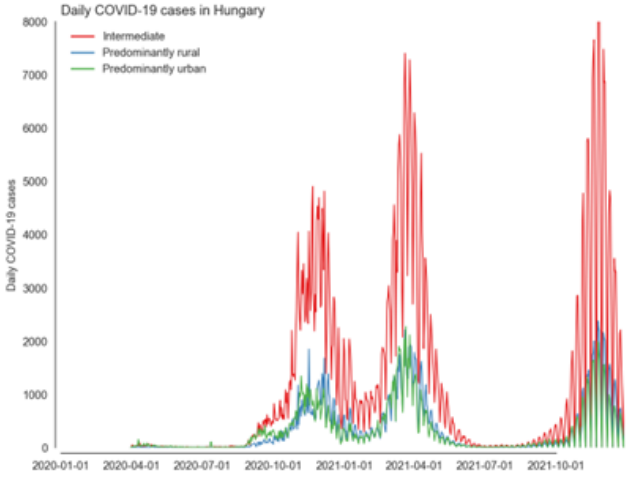


COVID-19 cases during the second wave



COVID-19 cases during the third wave





During the study timeframe, Hungary saw mainly **four COVID-19 waves**; in which the first reached the peak on April, 9, 2020, the second on December, 24, 2020, the third on March, 21, 2021, and the fourth on December, 08, 2021.

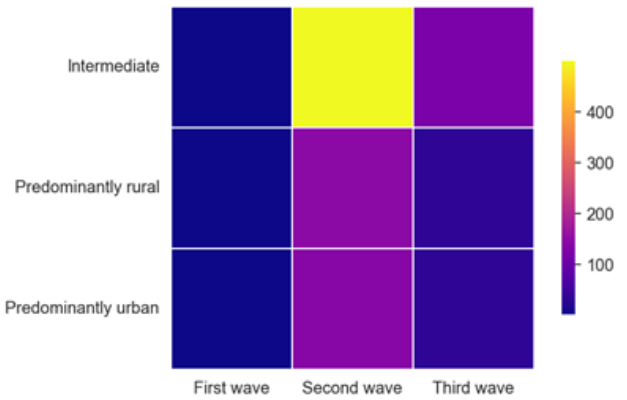
During the first wave, predominantly urban areas were the most affected by the virus and have reported the highest COVID-19 cases such as disclosed in Budapest region. Followed by intermediate regions such as reported in the regions of Pest, and Fejér.

During the second wave, COVID-19 cases increased espaically in intermediate regions such as reported in Pest, Borsod-Abaúj-Zemplén, Hajdú-Bihar, and Győr-Moson-Sopron. However, the urban region of Budapest still accounts the highest number of COVID-19 cases. It it important to highlight that predominantly rural regions were less hit by the virus such as in Szabolcs-Szatmár-Bereg region or in Somogy.

During the third wave, the overall number of COVID-19 cases has decreased in all regions following the same pattern, espacially, for intermediate regions as reported in Pest, Borsod-Abaúj-Zemplén, Bács-Kiskun, Jász-Nagykun-Szolnok, Hajdú-Bihar, and Csongrád. However, the urban region of Budapest still ranking the first in terms of COVID-19 infection cases.

When taking population dynamics and regional characteristics into account, we found that intermediate regions represent 65% of the total regions and host 64% of the total population, while predominantly rural regions represent 30% and host 19% of the total population in Hungary. Therefore, intermediate are more likely to get hit by the virus considering their share of the total population and regional distribution.

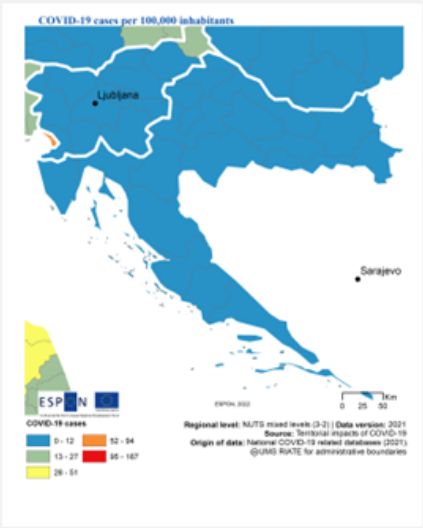
Overall, intermediate regions were the most hit by the virus (counting 65% of the total cases across the three waves), followed by predominantly rural regions (18%), and urban region (17%).



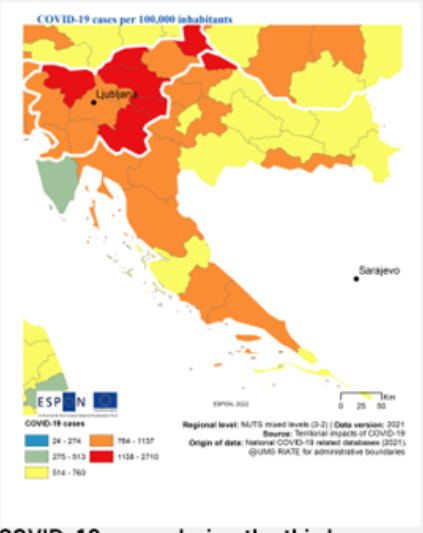
Total COVID-19 cases	Hungary	Number of regions	Data source
22-06-2022 1.92M		20 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 20 – Spatial diffusion of the COVID-19 in the East-Central region (case of Croatia)

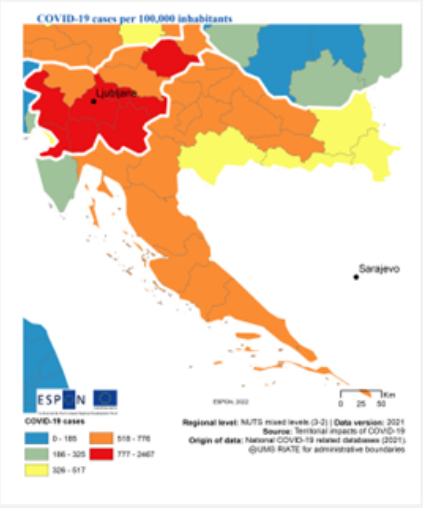
COVID-19 cases during the first wave

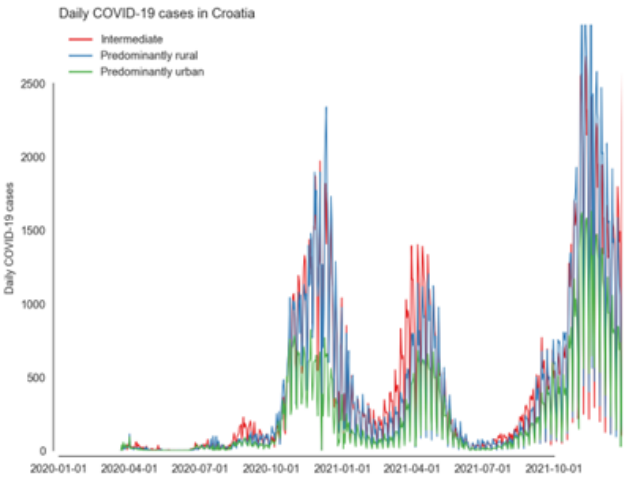


COVID-19 cases during the second wave



COVID-19 cases during the third wave





During the study timeframe, Croatia saw mainly **four COVID-19 waves**; in which the first reached the peak on March, 23, 2020, the second on November, 27, 2020, the third on April, 06, 2021, and the fourth on December 10, 2021.

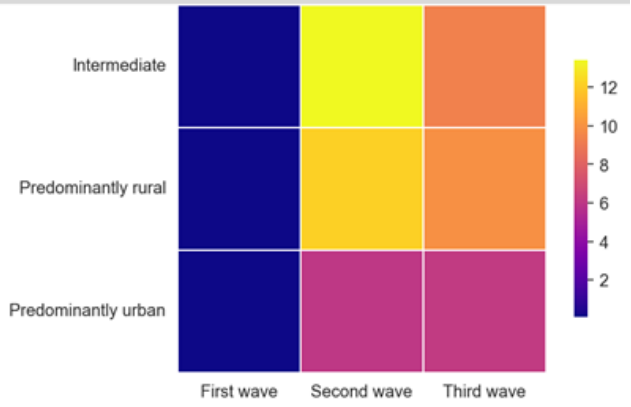
During the first wave, predominantly urban areas were the most affected by the virus and have reported the highest COVID-19 cases such as disclosed in Grad Zagreb region. Predominantly rural areas were also severly hit by the virus during this wave, where the regions of Zagrebačka županija, Krapinsko-zagorska županija reported the highest values.

During the second wave, COVID-19 cases increased espaically in intermediate regions such as reported in Splitsko-dalmatinska županija, and Primorsko-goranska županija. But also for predominantly rural regions such as in Zagrebačka županija, and Međimurska županija.

During the third wave, the overall number of COVID-19 cases has decreased in all regions following the same pattern, espacially, for intermediate regions as reported in Podravska, Savinjska, and Jugovzhodna Slovenija.

When taking population dynamics and regional characteristics into account, we found that intermediate regions represent 57% of the total regions and host 69% of the total population, while predominantly rural regions represent 43% and host 31% of the total population of Croatia. Therefore, intermediate are more likely to get hit by the virus considering their share of the total population and regional distribution.

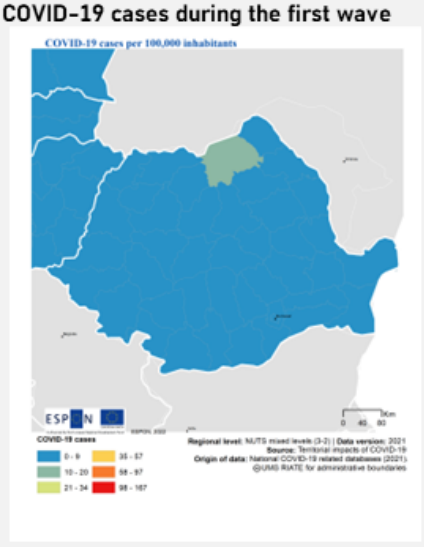
Overall, intermediate regions were the most hit by the virus (counting 79% of the total cases across the three waves), followed by predominantly rural regions (30%).



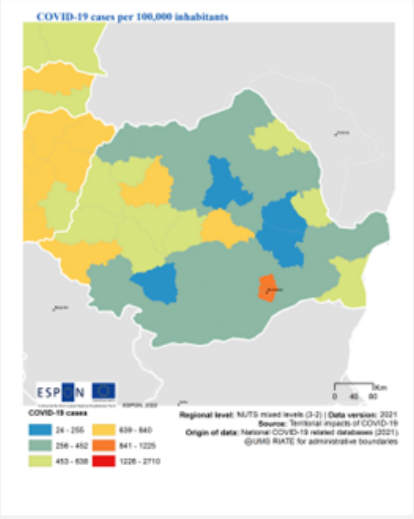
Total COVID-19 cases		Number of regions	Data source
22-06-2022 1.14M	**Croatia**	21 regions NUTS3 (2021)	COVID-19 European Regional Tracker

Box 21 – Spatial diffusion of the COVID-19 in the East-Central region (case of Romania)

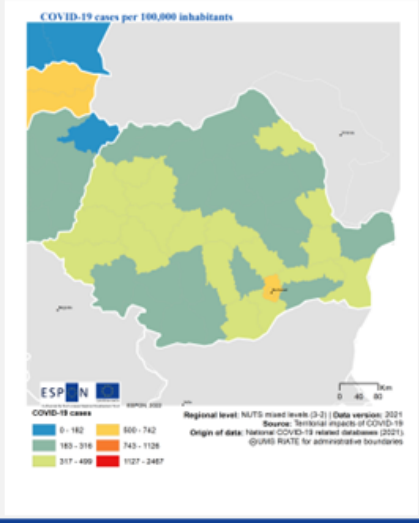
COVID-19 cases during the first wave

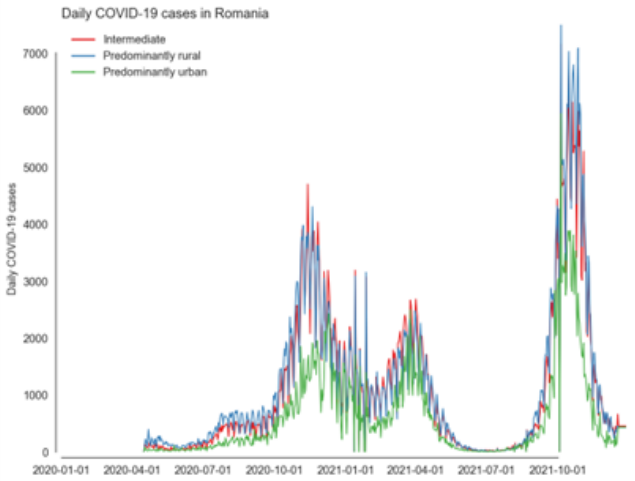


COVID-19 cases during the second wave



COVID-19 cases during the third wave





The figure shows the daily COVID-19 cases evolution by types of regions (urban, intermediate, and rural). During the study timeframe, Romania saw mainly **three COVID-19 waves**; in which the first reached the peak on October, 21, 2020, the second on March, 17, 2021, the third on October, 11, 2021.

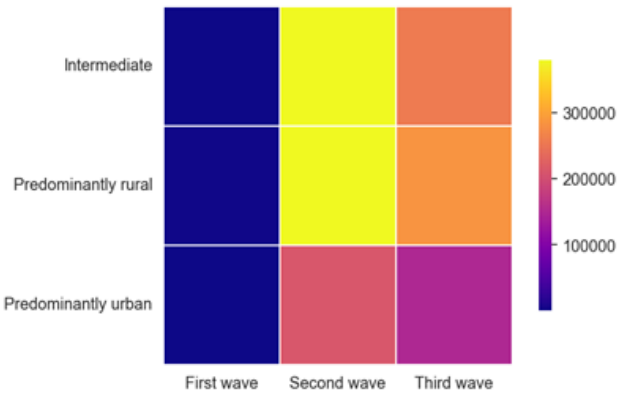
During the first wave, predominantly rural regions (e.g., Suceava, Bihor, and Bacau) were the most effected by the pandemic, followed by intermediate regions (e.g., Arad, Brasova, and Hunedoara) counting the highest number of COVID-19 infection cases. Surprisingly, urban regions were less hit by the pandemic (e.g., Bucuresti, Ilfov).

During the second wave, the infection number of COVID-19 infections grows dramatically and infiltrates into all of the Roman regions. Both intermediate regions and predominantly rural regions were hit by the pandemic with the same magnitude. Notice that during the second wave Bucuresti (urban region) accounts the highest number of COVID-19 cases across all Romanian regions.

During the third wave, the infection number in Romania across all regional typologies decreases following the same infections pattern, meaning that predominantly rural regions are still experiencing the highest COVID-19 total infection cases.

When taking population dynamics and regional characteristics into account, we found that rural regions represent 67% of the total Romania regions and host 53% of the total Romanian population, while intermediate regions represent 29% and host 35% of the total population, and urban regions represent 5% and host 12% of the total population. Therefore, rural and intermediate regions are more likely to get hit by the virus considering their number and share of the total Romanian population.

Overall, Romanian rural regions were the most hit by the virus (counting 40% of the total cases across the three waves), followed by intermediate regions (38%) and predominantly urban regions (22%).



Total COVID-19 cases	Romania	Number of regions	Data source
22-06-2022 2.92M		42 regions NUTS3 (2021)	COVID-19 European Regional Tracker

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