An Index-Based Vulnerability Assessment of Philippine Provinces and NCR Cities and Municipality Against COVID-19

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Abstract

Objective: This study aimed to construct vulnerability index for COVID-19 (VICov-19) to assess the coping capacity and resiliency of local areas in the Philippines.

Methods: VICov-19 used a different perspective in measuring vulnerability by incorporating severity, infrastructure, poverty and family structure dimensions. The study used the Analytical Hierarchy Process or AHP to weight the importance of indicator data. Using these weights, the indicator data were aggregated to come up with dimension scores which were further aggregated using zero-corrected geometric mean to come up with VICov-19. All analyses were implemented in relevant softwares such as Microsoft Excel, R, STATA and GEODA.

Results: The index identified 22 most vulnerable local areas including the cities and municipality of National Capital Region which is the current epicenter in the Philippines. The index was able to capture local areas with high counts of detected cases and showed favorable agreement to the counts in terms of rank. The identified most vulnerable local areas also showed consistency across selected date intervals.

Discussion: The impact of severity substantially influences VICov-19 to classify the province as most vulnerable. The mean severity and poverty scores of local areas classified as most vulnerable were way higher than moderate and least levels. On the other hand, higher vulnerability in terms of infrastructure and family structure dimension scores resulted to lower overall vulnerability which can be attributed to industrialization of involved local areas. Results suggest expanding the coping capacity by focusing on infrastructure and poverty situation of local areas.

Keywords: coping capability, local area statistic, COVID-19, analytical hierarchy process

Introduction

Recently, Philippine government placed the entire Luzon under enhanced community quarantine to manage COVID-19 situation in the country [1]. So far, COVID-19 has escalated to many cases around the globe [2] and reached 5,223 confirmed cases with 335 deaths and 295 recoveries in the Philippines as of April 14, 2020 [3].

Though there are competing vaccines currently undergoing trials, there is an urgent need to spot and confine the spread of COVID-19. The key is to detect the impending nationwide spread of COVID-19 to halt mortality and its impending effect to economy. For this reason, this study constructed local area vulnerability index for COVID-19 (VICov-19).

Vulnerability is the susceptibility or propensity to be affected by adverse outcomes by merging risk and protective factors. A unit is vulnerable if its ability to respond effectively and solve the hazard productively is lower than the impact imposed by the hazard [4, 5 ,6]. This study defines vulnerability as the level of coping capacity and resiliency

of local areas in the Philippines against the impact brought about by COVID-19 pandemic. The vulnerability was measured by an index (VICov-19) which incorporated not only the severity of COVID-19 but also infrastructure, poverty and family structure of the locality.

VICov-19 can be used in monitoring, evaluating and modelling the current situation of local areas in the Philippines. It can also encourage the locality to set up adaptive capacity by expanding their competencies against COVID-19. Moreover, identifying vulnerable local areas can also provide information on which local area needs extended or relaxed community quarantine.

Methods

The study came up with four dimensions of vulnerability after performing factor analysis using maximum-likelihood estimation procedure. Here are the dimensions of VICov-19 and relevant indicators.

1. Severity dimension describes the current situation of local areas by accounting for morbidity. Indicators include (1) number of detected cases, and (2) number of patient under investigation (PUI). Number of detected cases and number of PUI were the reported cumulative positive cases of the local government from April 3 to 8. The number of cleared, discharged and deaths were subtracted accordingly from the reported PUI counts.

2. Infrastructure dimension portrays the strength of healthcare workforce and contribution of the environment that allow or limit the spread of an epidemic. Indicators include (1) number of government physicians, (2) number of hospital and infirmary, (3) number of

accommodation establishments, (4) number of public health nurses, and (5) number of rural health units.

3. Family structure dimension emphasizes the role of family structure that enhances disease transmission. Indicators include (1) average family size, and (2) proportion of senior population aged at least 60 years old.

4. Poverty dimension dictates the extent and value of resources that needs to be prepared under epidemic threats. Indicators include (1) population density, and (2) poverty incidence

All indicators were standardized accordingly using the 2015 population count per local areas and were normalized from 0.0 (lowest vulnerability) to 1.0 (highest vulnerability). Weights for each indicator were derived through Analytical Hierarchy Process [7, 8, 9, 10, 11] by collecting opinions from the authors and recruited experts from the field of medicine, epidemiology and public health in general. Weights are shown in Table 3.

A score per dimension was calculated by multiplying the weight to the corresponding normalized indicator. Dimension scores were aggregated using this zero-corrected geometric mean formula.

$$\text{VICov-19} = \sqrt[4]{\prod_{i=1}^{4} \text{dimension}_i + 0.00001} - 0.00001$$

To evaluate VICov-19, indices were also calculated for the periods of March 24-26 and March 29 – April 2. The local areas were then ranked in these dates and these ranks were compared to tie-adjusted rank of the local area based from the number of actual

cases. To check for consistency, the identified most vulnerable local areas were compared across date intervals.

Results

Table 1 shows the weights of indicators per dimension derived from AHP. Among the five infrastructure indicators, number of government physicians per 100,000 population had the highest weight of 24.25%. For other dimensions, population density got a weight of 65.79% in poverty dimension, average family size got 51.38% in family structure dimension while number of detected cases per 100,000 population got 63.11% in severity dimension.

Table 1. Indicator weights per dimension.

Indicator	Weight
Infrastructure Dimension (per 100,000 population)	
Number of government physicians	0.2425
Number of hospital and infirmary	0.2048
Number of accommodation establishments	0.1991
Number of public health nurses	0.1891
Number of rural health units	0.1645
Poverty Dimension	
Population density	0.6578
Poverty incidence	0.3422
Family Structure Dimension	
Average family size	0.5138
Proportion of senior population (≥ 60)	0.4862
Severity Dimension (per 100,000 pop)	
Number of detected cases	0.6311
Number of patient under investigation (PUI)	0.3689

VICov-19 revealed National Capital Region or NCR and some isolated provinces as most vulnerable local areas. NCR is currently the epicenter in the Philippines. The map showing the locations of most, moderately, and least vulnerable local areas are shown in

Figure 1 while Appendix Table 1 shows the normalized VICov-19 for each local area. Local areas with VICov-19 less than 0.22 were categorized under least vulnerable local areas while those with VICov-19 higher than 0.44 were categorized as most vulnerable. The rest were categorized as moderately vulnerable local areas.

VICov-19 identified NCR as a hotspot of vulnerable local areas. Due to a different lens used by VICOV-19, provinces surrounding NCR with high normalized actual cases were identified by VICov-19 as least to moderately vulnerable only. Aside from NCR, isolated most vulnerable local areas appeared in other parts of the country while moderately vulnerable local areas are widely spread creating clusters throughout the country. Clusters of least vulnerable local areas were found in Bicol Region (V) and in CARAGA Region (XIII).

To evaluate VICov-19, this study also calculated indices for the periods March 24-26 and March 29 – April 2. Results of the comparison of ranks are shown in Figure 2. Generally, it can be observed that mean absolute change in rank were lower in vulnerable classes and were observed to increase in least vulnerable classes. Therefore, VICov-19 is sensitive to declare local areas as most vulnerable if they have higher number of cases. However, due to tied ranks in actual cases of least vulnerable local areas, VICov-19 did not perform well in identifying least vulnerable local areas. Therefore, it is expected that VICov-19 can spot vulnerable local areas, of any level, as new data come in.

Using the 0.44 cutoff, presented in Table 2 are the most vulnerable local areas per date interval. Thirteen (13) local areas were identified as most vulnerable in all date intervals while ten (10) local areas were identified as such in two date intervals. On the other hand, nine (9) local areas appeared only once. This indicated desirable consistency

for VICov-19 since identified most vulnerable local areas did not drastically changed across date intervals specifically among top vulnerable localities.

Table 2. Most vulnerable local areas (VICov-19 > 0.44) across date intervals.

Rank	Date Interval		
	Mar 24 - 26	**Mar 29 – Apr 2**	**Apr 3 – Apr 8**
1	City of San Juan	City of San Juan	City of San Juan
2	City of Makati	City of Mandaluyong	City of Mandaluyong
3	City of Mandaluyong	City of Makati	City of Manila
4	Aurora	City of Manila	City of Makati
5	City of Parañaque	Aurora	Aurora
6	Romblon	City of Parañaque	City of Parañaque
7	City of Manila	Bohol	Pasay City
8	Marinduque	Pateros	City of Navotas
9	Bohol	Romblon	Quezon City
10	Occidental Mindoro	Occidental Mindoro	City of Marikina
11	Northern Samar	City of Muntinlupa	City of Malabon
12	Negros Oriental	Northern Samar	City of Muntinlupa
13	Pasay City	Apayao	Pateros
14	Misamis Occidental	City of Navotas	City of Pasig
15	Mountain Province	Pasay City	Bohol
16	Siquijor	Negros Oriental	Taguig City
17	City of Muntinlupa	Eastern Samar	City of Valenzuela
18	City of Pasig	Caloocan City	Mountain Province
19	Eastern Samar	Siquijor	Caloocan City
20	Samar (Western)	Misamis Occidental	Northern Samar
21	Taguig City	Southern Leyte	City of Las Piñas
22	Lanao del Sur	City of Malabon	Misamis Occidental
23		Taguig City	
24		Mountain Province	

Legend: ☐ classified twice ☐ classified thrice

Discussion

A. Impact of severity and poverty

Most evident trend in the results was the impact of severity happening in the local areas. High counts of cases and PUIs substantially increases VICov-19 classifying the province or city as most vulnerable. Most of the cities in NCR, the epicenter in the

Philippines, are listed as most vulnerable by VICov-19. On the other hand, local areas found at the end of the list and are classified as least vulnerable are those with low counts of detected cases and PUIs. This is evident in Figure 3. The mean severity score (mean = 0.19) of local areas classified as most vulnerable was way higher than the other two levels (mean = 0.01, 0.04).

B. Impact of poverty

Poverty also played an important role. Higher mean poverty score (mean = 0.22) was observed among provinces classified as most vulnerable. In fact, mean poverty score was increasing from least to highest level of vulnerability (mean = 0.13, 0.14). Poverty dimension is more than just describing the extent of available resources to provide essential needs of the province. Measuring poverty and presence of resources during epidemics is about long-run resiliency and identifies financial and logistical type of support. City of Manila and City of Mandaluyong both received high scores in poverty dimension and these local areas were classified as most vulnerable. Other local areas with high poverty scores that were categorized as most vulnerable were Pasay City (Rank 7), City of Navotas (Rank 8), Caloocan City (Rank 19), and Northern Samar (Rank 20). Moreover, Bohol (Rank 15) had high family structure score and was also identified as most vulnerable.

C. Impact of infrastructure and family structure

A different trend can be observed in the infrastructure and family structure dimensions in which mean scores were decreasing from least to highest level of vulnerability. Though it was expected that superior infrastructure leads to low vulnerability,

it was noted that most of the areas that were categorized as most vulnerable were those with superior infrastructure. It should be emphasized that this result does not suggest ignoring infrastructure. The reason behind this trend is the fact that these local areas were the highly industrialized areas and at the same time were the local areas with high severity scores. The same reason is true in family structure dimension. Due to industrialization among most vulnerable local areas, most of them belonged to the working population leading to smaller number of senior citizens and smaller family sizes.

D. Vulnerability of local areas with small number of reported cases and PUIs

Another important trend to note are the local areas classified as most vulnerable even if there are still no to few recorded cases and PUIs. Examples are Aurora and Mountain Province with no reported detected case, Northern Samar, Misamis Occidental, City of Las Piñas and Caloocan City with very low number of detected cases and PUIs, all as of April 8. This suggested that resilience to COVID-19 is not just about detection of cases but also depends on the capacity of the local area to effectively respond to this growing pandemic.

E. Importance of identifying vulnerable local areas

Recognizing vulnerable local areas is not just about identifying who needs help and who should not be complacent. Discovering vulnerable local areas can delay or more importantly halt the spread across provinces. Stricter lockdown or quarantine procedures can be beneficial to these vulnerable provinces. It will not only benefit the local area, but it will also help in protecting adjacent ones.

Severity and poverty dimensions play a vital role in the index since poor individuals tend to have little access to healthcare and other basic needs like food and sanitation. Therefore, amelioration programs to aid local areas can extensively help during pandemics like COVID-19. More critically, investments to strengthen public health systems as suggested by the infrastructure dimension should be considered. Any nation can do it if they have the right infrastructure in place.

If there is any certainty about emerging infections, it is positive that they will continue to emerge. However, the idea of which disease will it be remains an uncertainty. If resources will be focused to combat COVID-19 and future infectious diseases, resources should be allocated to strengthening the Philippines capacity to detect and respond to diseases rather than waiting for it to grow without awareness. Indeed, failing to plan is planning to fail.

Illustrations

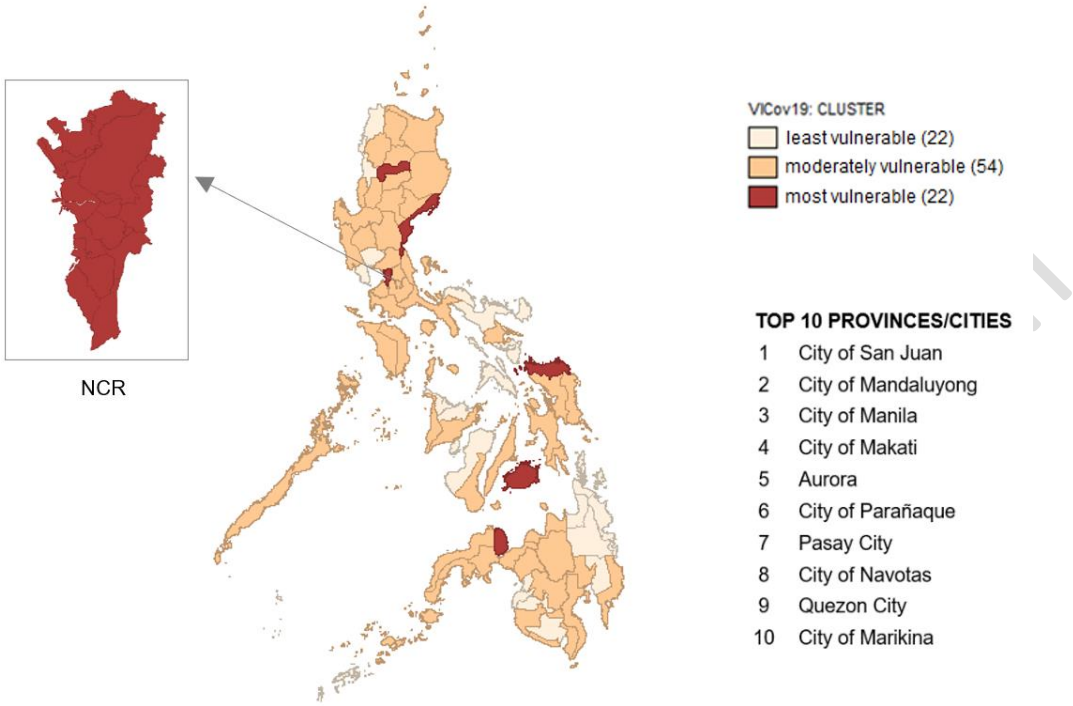
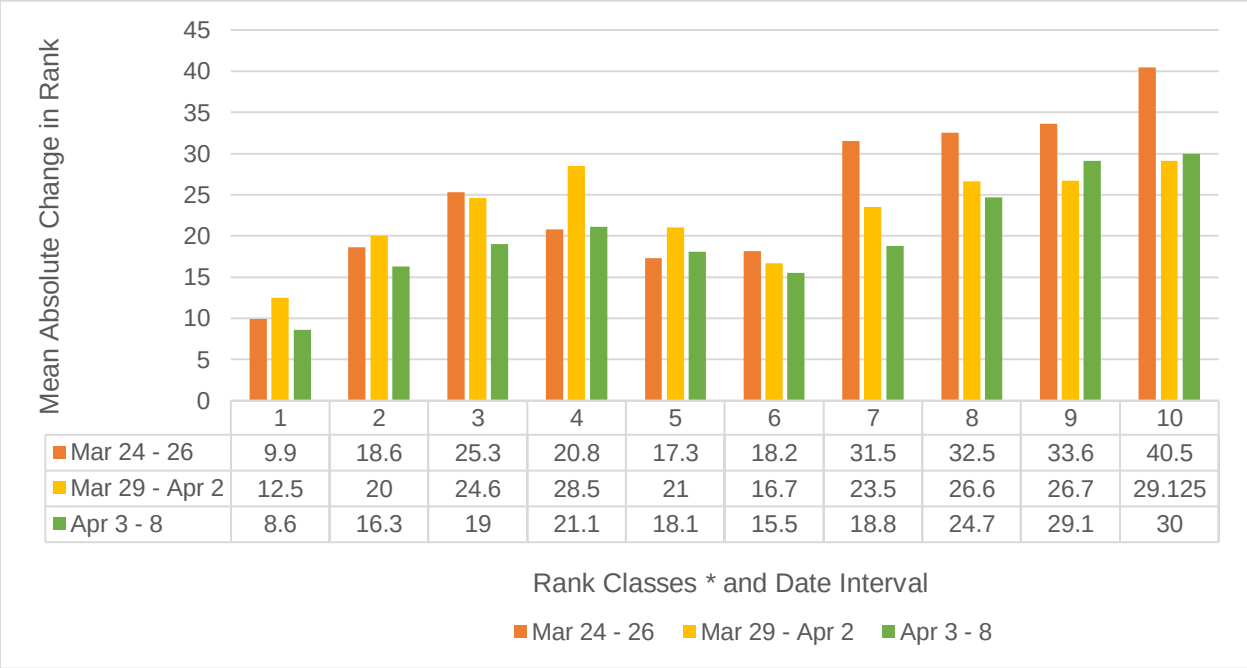


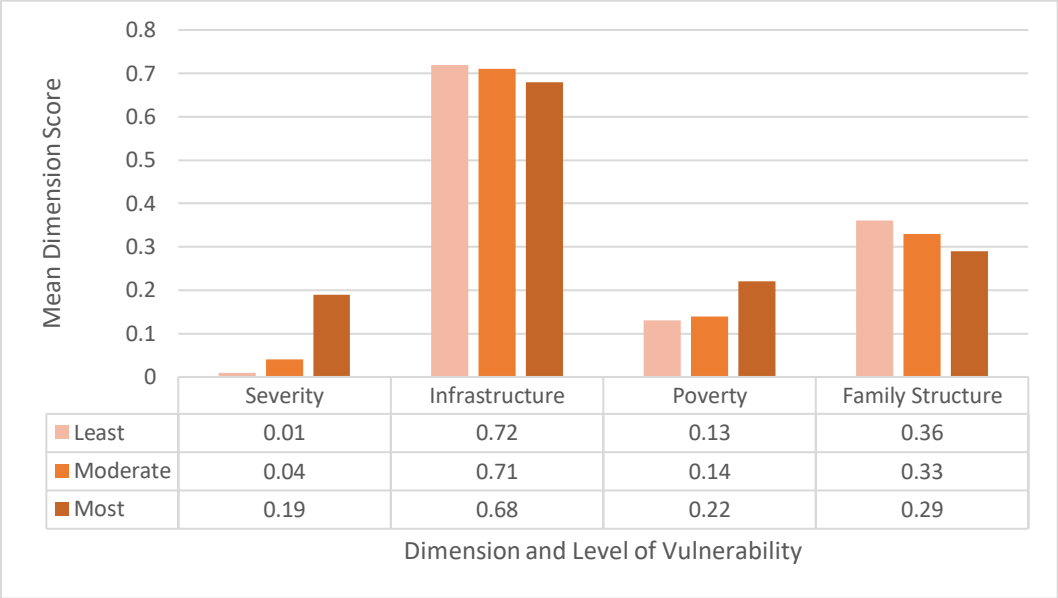
Figure 1. Local areas in the Philippines according to level of vulnerability based on VICov-19.



	1	2	3	4	5	6	7	8	9	10
Mar 24 - 26	9.9	18.6	25.3	20.8	17.3	18.2	31.5	32.5	33.6	40.5
Mar 29 - Apr 2	12.5	20	24.6	28.5	21	16.7	23.5	26.6	26.7	29.125
Apr 3 - 8	8.6	16.3	19	21.1	18.1	15.5	18.8	24.7	29.1	30

* Class 1 included most vulnerable local areas while Class 10 included the least vulnerable local areas based from VICov-19 ranking for the period April 3 to 8.

Figure 2. Mean absolute change in ranks per class across date intervals.



** Low dimension core = low vulnerability, high dimension score = high vulnerability

Figure 3. Mean dimension score across level of vulnerability.

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Appendix

Table 1. VICov-19 and rank of Philippine provinces and NCR cities and municipality.

LOCAL AREA	VICov-19	RANK
NATIONAL CAPITAL REGION (NCR)		
CITY OF MANILA	0.8007	3
CITY OF MANDALUYONG	0.8397	2
CITY OF MARIKINA	0.5133	10
CITY OF PASIG	0.4993	14
QUEZON CITY	0.5416	9
CITY OF SAN JUAN	1.0000	1
CALOOCAN CITY	0.4563	19
CITY OF MALABON	0.5114	11
CITY OF NAVOTAS	0.5427	8
CITY OF VALENZUELA	0.4603	17
CITY OF LAS PIÑAS	0.4519	21
CITY OF MAKATI	0.7559	4

LOCAL AREA	VICov-19	RANK
CITY OF MUNTINLUPA	0.5092	12
CITY OF PARAÑAQUE	0.6015	6
PATEROS	0.5082	13
PASAY CITY	0.5432	7
TAGUIG CITY	0.4705	16
CORDILLERA ADMINISTRATIVE REGION (CAR)		
ABRA	0.3863	30
APAYAO	0.3604	37
BENGUET	0.2510	64
IFUGAO	0.2768	55
KALINGA	0.3692	34
MOUNTAIN PROVINCE	0.4567	18
REGION I - ILOCOS REGION		
ILOCOS NORTE	0.1111	91
ILOCOS SUR	0.1896	83
LA UNION	0.4054	28
PANGASINAN	0.2325	72
REGION II - CAGAYAN VALLEY		
BATANES	0.3692	35
CAGAYAN	0.3358	44
ISABELA	0.2652	59
NUEVA VIZCAYA	0.3059	50
QUIRINO	0.2761	56
REGION III - CENTRAL LUZON		
AURORA	0.6386	5
BATAAN	0.1447	90
BULACAN	0.2342	70
NUEVA ECIJA	0.3448	42
PAMPANGA	0.2176	78
TARLAC	0.4190	25
ZAMBALES	0.3060	49
REGION IVA - CALABARZON		
BATANGAS	0.3554	39
CAVITE	0.2886	54
LAGUNA	0.2979	51
QUEZON	0.3665	36
RIZAL	0.3149	46
REGION IVB - MIMAROPA		
MARINDUQUE	0.4086	27
OCCIDENTAL MINDORO	0.4337	23
ORIENTAL MINDORO	0.2495	66
PALAWAN	0.2302	73
ROMBLON	0.3792	31

LOCAL AREA	VICov-19	RANK
REGION V - BICOL REGION		
ALBAY	0.2283	75
CAMARINES NORTE	0.1554	88
CAMARINES SUR	0.1666	86
CATANDUANES	0.1967	82
MASBATE	0.0000	98
SORSOGON	0.0980	93
REGION VI - WESTERN VISAYAS		
AKLAN	0.2191	77
ANTIQUE	0.2392	69
CAPIZ	0.2003	81
GUIMARAS	0.0751	95
ILOILO	0.2739	57
NEGROS OCCIDENTAL	0.2033	80
REGION VII - CENTRAL VISAYAS		
BOHOL	0.4791	15
CEBU	0.3579	38
NEGROS ORIENTAL	0.3781	32
SIQUIJOR	0.4281	24
REGION VIII - EASTERN VISAYAS		
BILIRAN	0.3538	41
EASTERN SAMAR	0.3538	40
LEYTE	0.2603	60
NORTHERN SAMAR	0.4562	20
SAMAR (WESTERN SAMAR)	0.3981	29
SOUTHERN LEYTE	0.4171	26
REGION IX - ZAMBOANGA PENINSULA		
ZAMBOANGA DEL NORTE	0.3762	33
ZAMBOANGA DEL SUR	0.2658	58
ZAMBOANGA SIBUGAY	0.2536	62
REGION X - NORTHERN MINDANAO		
BUKIDNON	0.2939	53
CAMIGUIN	0.3438	43
LANAO DEL NORTE	0.3116	48
MISAMIS OCCIDENTAL	0.4406	22
MISAMIS ORIENTAL	0.2502	65
REGION XI - DAVAO REGION		
COMPOSTELA VALLEY	0.1600	87
DAVAO DEL NORTE	0.2492	68
DAVAO DEL SUR	0.2519	63
DAVAO ORIENTAL	0.2947	52
DAVAO OCCIDENTAL	0.2328	71
REGION XII - SOCCSKSARGEN		

LOCAL AREA	VICov-19	RANK
COTABATO (NORTH COTABATO)	0.2587	61
SARANGANI	0.2493	67
SOUTH COTABATO	0.2071	79
SULTAN KUDARAT	0.2296	74
REGION XIII - CARAGA		
AGUSAN DEL NORTE	0.1708	85
AGUSAN DEL SUR	0.0814	94
DINAGAT ISLANDS	0.0011	96
SURIGAO DEL NORTE	0.0996	92
SURIGAO DEL SUR	0.0000	97
AUTONOMOUS REGION IN MUSLIM MINDANAO (ARMM)		
BASILAN	0.3279	45
LANAO DEL SUR	0.3117	47
MAGUINDANAO	0.1843	84
SULU	0.2279	76
TAWI-TAWI	0.1469	89