

Research Article

Geospatial mapping of COVID-19 cases, risk and agriculture hotspots in decision-making of lockdown relaxation in Nepal

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Received: May 23, 2020; Accepted: June 14, 2020; Published: June 25, 2020

Abstract: The study has explored the risk scenario *via* geospatial mapping of temporal transmission trend of COVID-19 in 77 districts of Nepal focusing on the district-wise risk analyses based on present active cases, population density and land entry points from neighboring countries. In overall, low to very high risk zones have been identified. Jhapa, Morang and Sunsari districts of Province 1; Dhanusa, Mahottari, Sarlahi, Rautahat, Bara and Parsa districts of Province 2; Kathmandu district of Bagmati Province, Nawalparasi West, Rupandehi, Kapilbastu and Banke districts of Province 5, as well as Kailali of Sudurpanchim Province are identified to have very high risk for COVID-19 spread. The rapid growth in the number of cases has made many districts remarkably susceptible to the infection. The vulnerability analysis has been then followed by identification of agriculture hotspots across the country in terms of major crops. 42 districts with moderate to high crop productivities have been recognized as being not in very high risk zones where the government should allow farmers to do their agriculture activities with well-maintained social distance and other safety precautions. The results when combined would suggest an urgent decision by the Government for gradual lockdown relaxation for agro-economic reinstatement what is commonly called the latent comparative advantage for Nepalese economy after tourism.

Keywords: COVID-19, GIS, risk analysis, agriculture, lockdown relaxation, agro-economy

सारांश: यो अनुसन्धानपत्रमा भौगोलिक सूचना प्रणाली (GIS) को प्रयोगद्वारा नेपालका ७७ जिल्लाहरूमा कोभिड - १९ रोगको संक्रमणको आवधिक प्रवृत्तिको लेखाजोखा गरेर संभावित जोखिमको परिदृश्यको आकलन गर्ने प्रयास गरिएको छ। विभिन्न जिल्लामा हाल जानकारीमा रहेका विरामीको संख्या, जनघनत्व र छिमेकी देशहरूबाट नेपाल आउने प्रवेश बिन्दुमा आधारित भएर जिल्लागत जोखिमको विश्लेषण गरिएको छ। समग्रमा कमदेखि उच्च जोखिममा पर्न सक्ने जिल्लाहरूको पहिचान गरिएको छ। प्रदेश १ मा अवस्थित झापा, मोरंग तथा सुनसरीस प्रदेश २ का धनुषा, महोत्तरी, सर्लाही, रौतहट, बारा र पर्सास वागमती प्रदेशको काठमाडौं तथा प्रदेश ५ का नवलपरासी, रुपन्देही(पश्चिम, कपिलवस्तु र बाँके तथा सुदूर पश्चिम प्रदेशको कैलाली कोभिड (१९ संक्रमणको धेरै उच्च जोखिमको पहिचान गरिएको छ। संक्रमणको संख्यामा भएको द्रुत बृद्धिले धेरै जिल्लाहरूलाई उल्लेखनिय रूपमा जोखिमयुक्त बनाएको छ। अध्ययनको दोस्रो खण्डमा देशको प्रमुख बालीको सन्दर्भमा देशभरिका कृषि हटस्पटहरूको पहिचान गरेर बालीनालीको अवस्थाको विश्लेषण प्रस्तुत गरिएको छ। मध्यमदेखि उच्च मात्रामा फसल उत्पादकत्व सामर्थ्य भएका तर कोभिड(१९ संक्रमणको हिसावले साह्रै उच्च जोखिममा पर्ने ४२ वटा जिल्ला पहिचान गरिएको छ जहाँ सरकारले किसानहरूलाई भौतिकसामाजिक दूरी कायम गरी सुरक्षा र सावधानीका साथ कृषि गतिविधि संचालन गर्न सहज गराउनु पर्ने देखिन्छ। नेपालको अर्थतन्त्रमा पर्यटन पछि तुलनात्मक लाभको दृष्टिले धेरै योगदान पुराउने कृषिजन्य कृषाकलापको पुनर्स्थापनाको लागि सरकारले क्रमिक रूपमा लकडाउनलाई खुकुलो बनाउने निती लिनु लाभदायी हुने यो अनुसन्धानको निष्कर्ष छ।

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1. Introduction

The outbreak of novel coronavirus disease (COVID-19), first discovered in Wuhan, China in December 2019, declared as a public health emergency of international concern which had infected more than 5.4 million cases and 346,434 deaths in more than 200 countries and territories around the world as of 24 May 2020 (World Health Organization [WHO], 2020). The first epicenter of COVID-19, Wuhan, issued a city lockdown order on 23 January 2020, in order to avoid spreading virus to other cities of the country. Unfortunately, over the next 2 months, the virus has been spread globally very speedily and each country had resorted to nationwide lockdown to hold transmission and necessary treatment. Italy made nationwide lockdown while U.S. had closed nonessential businesses and ordered residents to stay home (Ren, 2020). It is observed that the simply locking down the peoples without other interventions is not the final solution. It might be problematic because of high unemployment rates and closing of businesses activity. The economy of every sector will be definitely affected adversely. Agriculture sector is also affected from this pandemic (Sahoo and Rath, 2020), when agriculture productivity plays vital role among main contributors to GDP. These lockdown days are also coincided with season of harvesting winter crops and plantation of new summer crops. So, the lag in any one phase, may simply terminate the entire process of farming thereby leading to massive loss in food production (Hossain, 2020).

The higher density of population and potential mass movement are one of the driven factor for spread of pandemic influenza (Merler and Ajelli, 2009); (Glass and Glass, 2008) whereas restriction in travel and/or border control slow-down international transmission at early stage (Bajardi et al., 2011; Tomba and Wallinga, 2008). Later on, controlled internal border plays important role in minimization of patients within domestic region (Wood et al., 2007). Likewise, effectiveness of quarantine at every border entry point relatively reduce risk of releasing infectious individuals into community (Nishiura et al., 2009). In case of Nepal, for the prevention and control of COVID-19, Nepal Government had issued a nationwide lockdown order from 24 March 2020 and still continues (as of 24 May 2020). Low and middle-income countries are suffering rapid and significant economic crisis from spread of COVID-19 and consequent lockdown measures. The experts and economists have regularly suggested to authorities about the gradual relaxation of lockdown, commencing from agriculture sector (Shrestha, 2020). The New Zealand government had introduced four level alert system, named as PREPARE, REDUCE, RESTRICT and finally LOCKDOWN as

per COVID-19 affected from an isolated household to spread over community and nationwide (New Zealand [NZ], 2020). The alert level might be different for different regions of country and allow activities as per alert level with necessary precautions.

The present statistics of active cases, geographic distribution along with international exposure, movement (Wells et al., 2020) and high population density directed towards the necessity of scientific and technological support for efficient risk zoning to manage and prevent of COVID-19 for economic restoration. GIS and spatial data models have capabilities to identify the spatial transmission of epidemic, spatial control and prevention, resource allocation (Zhou et al., 2020), risk analysis (Pathirana, 2009), major economic hotspots along with geographic correlation between these variables with disease outbreaks (Mollalo et al., 2020).

The major objective of this paper is to focus on spatial temporal analysis of transmission trend of COVID-19, district-wise risk analysis and identification of agriculture hotspots for decision making in lockdown relaxation and agro-economic reinstatement within country Nepal with limited infrastructures and resources to fight against this pandemic.

2. Materials and Methods

The study was conducted in 77 districts of whole Nepal. The updated geometric shapefile of political and administrative boundary of Nepal was obtained from Survey Department under Government of Nepal (DoS, 2020). The study area is geographically located between 26° to 31°N latitudes and 80° to 89°E longitudes. The everyday updated data of COVID-19 cases throughout the nation are collected from Ministry of Health and Population daily press release (MoHP, 2020). The nationwide population and population density data of each districts are available on Central Bureau of Statistics for the year of 2011 (CBS, 2014). The major border entry points are compiled as per establishment of entry/exit points under Department of Immigration. Other land entry points at border are digitized with the intersection of road network and international boundary of Nepal. The data related to agriculture productivity of each district for the recent year of 2018 was collected from the report of Inter Provincial Dependency for Agricultural Development under Department of Agriculture (MoALD, 2018).

As of 24 May 2020, there are not exact vaccines developed for treatment of COVID-19. However, many ongoing scientific trials are evaluating potential treatments. The well informed about the symptoms of corona virus disease and keep social

distancing slow down its spread locally as well as globally. But COVID-19 has been spread more than 200 countries around the world and still remains unknown about the trajectory of transmission. The flow of people from foreign countries via land transportation without necessary medical measures and densely populated urban area having active cases of COVID patients may lead region to high risk. Nepal is also facing the fear of COVID-19, which is necessary to eliminate physically as well as mentally for the restoration of normal life. Thus, necessary to understand the relative risk of various factors affecting the spread of coronavirus disease for decision making in relaxation of lockdown and economic reinstatement. In decision making, the

weighted sum model (WSM) is the simplest and best multi-criteria decision analysis (MCDA) approach for evaluating number of ranked options from low to high as a decision possibility (Triantaphyllou, 2000; Abdulahi 2020). So, the multi-criteria spatial analysis under GIS platform is based on concept of weighted sum of assigned weights of each region of multiple layers. The model had generated the output by multiplying designated field values of each input raster data by assigned weight and then sums all input raster layers together to create an output raster dataset, which had shown the final alternatives ranked from 1 to 5 for decision making on very low risk district to very high risk districts for COVID-19 throughout 77 districts of Nepal.

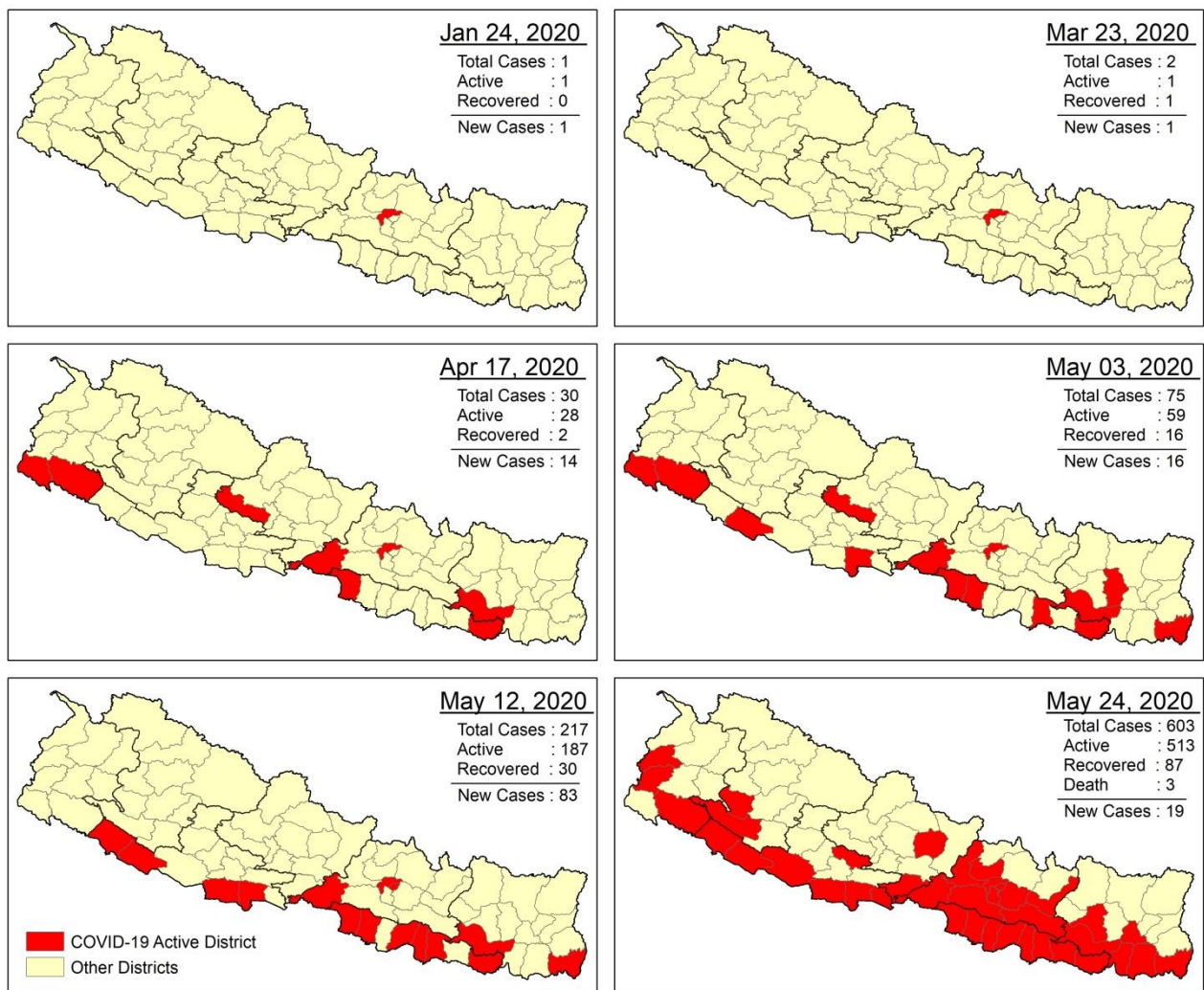


Figure 1. Time series distribution of COVID-19 active cases in Nepal

3. Results and Discussion

3.1 Active Cases of COVID-19

A Nepalese citizen, who had returned from China to Nepal was the first confirmed case of coronavirus disease in Nepal on 24 January 2020 in Kathmandu district. The second case was also seen in Kathmandu district almost after two months of first

case of corona patient. Thereafter, it was gradually increased and confirmed in different districts of Nepal. Fourteen new cases were confirmed in Udayapur district on 17 April 2020, which was the first big number of confirmed cases of coronavirus disease in Nepal in a single day. Furthermore, 16 new cases confirmed on 3 May 2020 and 83 new

cases after 9 days, almost 3 times increase in total as shown in **Figure 1**. The current statistics of COVID-19 in Nepal are 603 total confirmed cases, 513 active cases and 87 recovered with 3 deaths as of 24 May 2020 (MoHP, 2020) in 42 districts.

Currently, the primary effort of all countries is to flatten the curve of corona infection cases. Intensify the testing capacity and tracking effort with proper treatment and quarantining plays vital role. The arise of daily cases seems decrease in some countries whereas still increasing in others as shown in **Figure 2** but not limited to (Worldometers, 2020). As quickly increase in number of tests (MoHP, 2020), Nepal has also recorded daily large number of COVID-19 infection cases as presented in **Figure 3**. The temporal increment of coronavirus cases in Nepal during lockdown period in an exponential growth rate with more vulnerable districts remarkably.

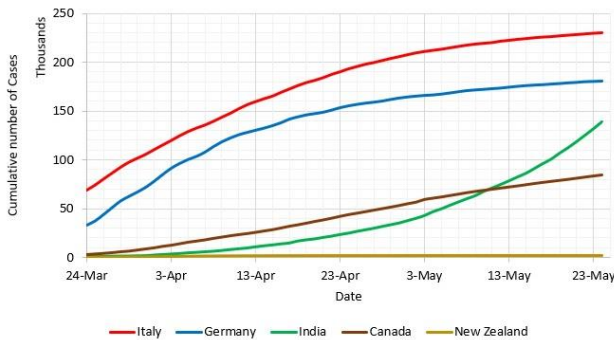


Figure 2. Time Series Spread of COVID-19 in Selected Countries

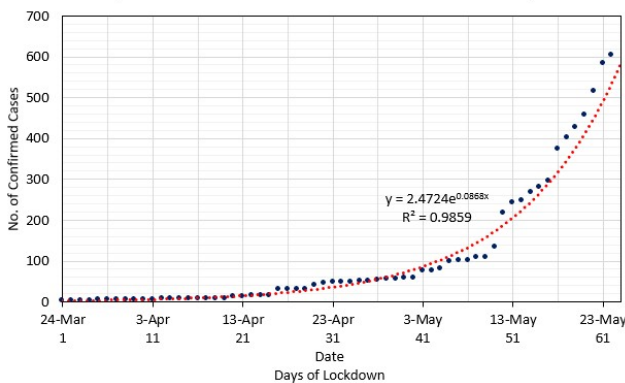


Figure 3. COVID-19 confirmed cases since lockdown in Nepal

The risk analysis considering of COVID active cases among all 77 districts of Nepal, had included the sub classification of all active cases into 5 zones as shown in **Figure 4**. The red zone indicates the very high-risk districts which have greater than 10 active cases. There are 7 very high-risk districts as of 24 May 2020, named as Jhapa, Sarlahi, Rautahat, Parsa, Rupandehi, Kapilbastu and Banke. The dark green zone indicates the very low-risk districts which have no active cases at current situation. Similarly, light green has less than 2, yellow have 3

to 5 and pink color zone have 6 to 10 active cases of COVID-19. Having more active patients may have chance to lead more spread of disease but not only limited to this factor. Some districts such as Udayapur, Kathmandu had high active cases at beginning but after recovered of more patients, it gradually reduces its active number and currently appears slightly lower to risk in term of COVID-19 active cases.

3.2. Population Density

The major key to control the outbreak of COVID-19 is to control/ reduce the contact rates, which depends upon population density of the region. High population density might lead to increase in contact rates of individuals, which reproduce larger numbers of patients and thus larger infectious disease outbreaks. It is found that the influenza transmission rates in India increase with the population density above 282 people per sq. km. (Carmona, 2020).

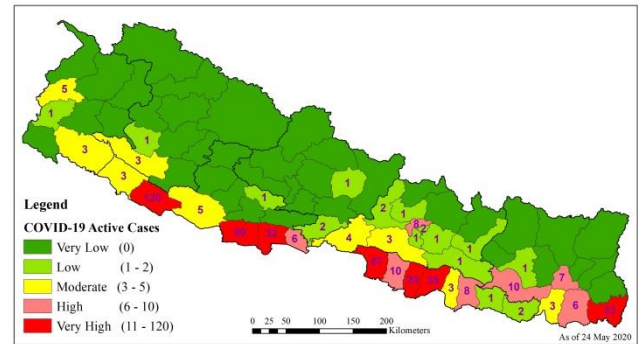


Figure 4. District-wise active cases of COVID-19

In case of Nepal, the central cities named as Kathmandu metropolitan city, Lalitpur and Bhaktapur have very high population densities (CBS, 2014) as shown in **Figure 5**.

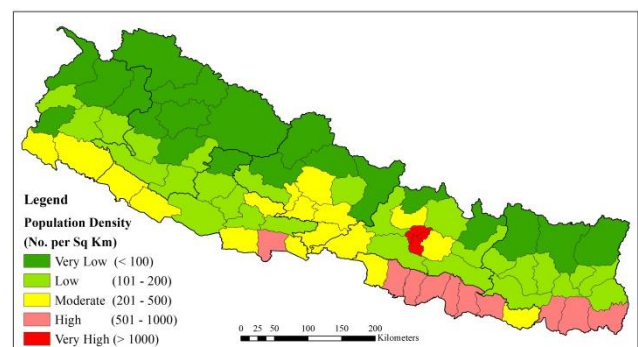


Figure 5. District-wise population density Map of Nepal

The districts with higher elevation at northern part have very low population as compared to area of districts. In the opposite, the districts along southern belt of Nepal have medium to high population densities. High population density may have also high movement, public activities and social contact, which might have risk of influenza transmission.

3.3. Entry Points of Nepal

The initial cause of coronavirus transmission is from exposure to international contacts for different purposes such as travel, trade and tourism. Later, intra-national movement of active patients is the medium of spreading. The major entry points of Nepal from its neighborhood country, India, having active cases of coronavirus are very highly vulnerable districts. The other entry points from India as well as major entry points through Tibet, China having no active case are also assigned as high risk districts. The remaining neighboring districts of high-risk districts are categorized as medium to low risk district as presented in **Figure 5**. The illegal movement of people from open land border (**Figure 6**) may lead significant risk to the adjoining districts.

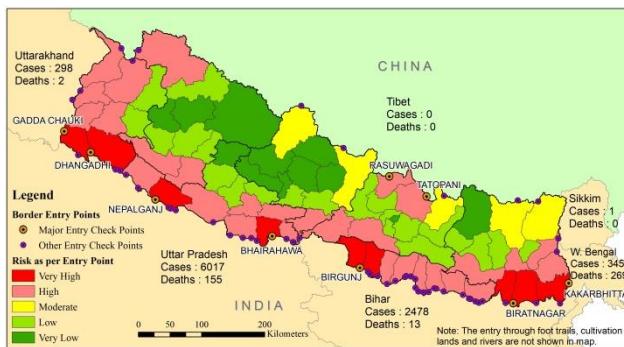


Figure 6. Land border entry points of Nepal

3.4. Agricultural Activities

Nepal is an agricultural country in which 66% of total population is directly engaged in farming. Agriculture is still the largest economic sector that solely contributes more than 30% of National GDP (MoALD, 2018). The major crops are paddy, wheat and maize. The summer crop plantation season starts from June to September. So, for the agro-economy reinstatement during and after lockdown, it is necessary to consider the agricultural activities too. The sum of agriculture production of paddy, wheat and maize of all 77 districts are categorized into 5 classes from very-low to very-high based on mean and standard deviation (Dharmasiri, 2009) of crop production throughout the nation. The districts along the southern belt of Nepal have high potential of agriculture crop production. The districts along the mid-range (middle mountain and sivalik) have also the moderate to high range of agriculture crop production as shown in **Figure 7**. The study mainly focusses on regulation of agriculture activities having moderate to very-high crop potential zone in consideration of COVID-19 risk as well.

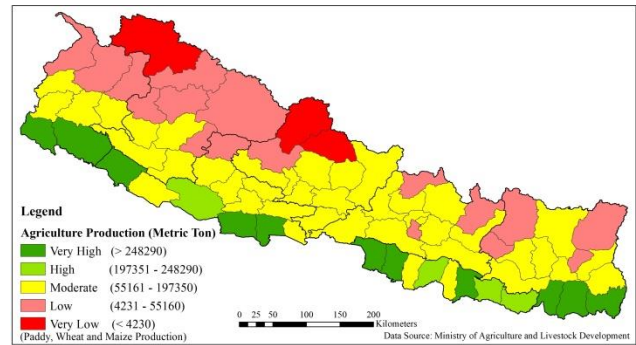


Figure 7. District-wise agriculture crop productivity map

3.5. Spatial Analysis

The relative risk of each parameter named as Active Cases of COVID-19, Population Density and Entry Points of Nepal are reclassified on 1 to 5 scale/weight from very low-risk to very-high risk respectively as shown in table 1. Then the geodatabase of each criteria used for model data was transformed from vector data into raster format database and further analysis for decision making.

Table 1. Risk Weight factor of Parameters

Criteria/ Ranking	COVID Risk Factor/Weight				
	Very Low	Low	Mod.	High	Very High
Active Cases	1	2	3	4	5
Pop ⁿ Density	1	2	3	4	5
Entry Points	1	2	3	4	5

The multi-criteria spatial analysis in GIS platform had generated the output by multiplying designated field values of each input raster data by assigned weight and then summed all input raster layers together to create a final output raster dataset. The result had shown the final alternatives ranked from 1 to 5 for decision making on very low risk district to very high risk districts for COVID-19 throughout 77 districts of Nepal as shown in **Figure 8**.

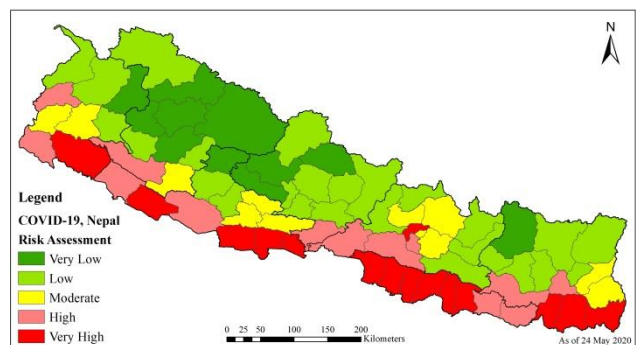


Figure 8. District-wise risk map of COVID-19, Nepal

Red zone describes the very high and high-risk zone for coronavirus disease. No activities are permitted in very high-risk zone, whereas only

controlled activities are allowed in high-risk zone. Likewise, yellow zone represents moderate risk zone, where minimum activities such as operation of limited public transport and agricultural works with taking in consideration of maximum precautions. Furthermore, green zone represents low and very low-risk zone, where the authority should give permission to open public transport and agricultural activities and essential industries with in-house lodging facilities for employees and maintain of physical distance. Thus, the government should move towards smart lockdown with restrictions in affected districts and partial loosening of restrictions in unaffected and/or less affected districts along-with opening of industries and agriculture as mention above to meet back the economic challenge.

The districts of province 1,3,5 and 7 have high potential of agriculture crop production. Some of the districts from Terai and Inner Terai have fertile land with high crop productivity such as Jhapa, Morang, Dhanusa, Bara, Parsa, Rupandehi and Kapilbastu, but lies in a very high-risk of coronavirus disease as shown in **Figure 9**. So, the restriction must be applied to all non-essential activities. The moderate to very high potential districts for crop production which lies in yellow and green zone should give permission for controlled agriculture activities for agro-economic reinstatement in Nepal.

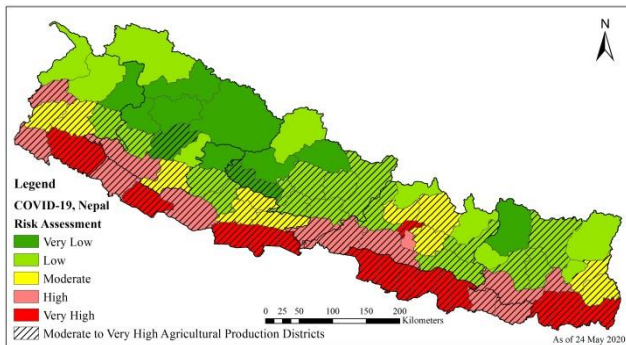


Figure 9. Spatial overlay of risk assessment and major agriculture zone

The disease crisis has coincided with harvesting season of winter crops and plantation season of summer crops such as paddy and maize. Thus, the government should allow farmers to do their agriculture activities within the marked safe regions, which are identified through the spatial overlay of COVID-19 risk zone and moderate to very-high crop potential zone of Nepal as shown in **Figure 10**. The activities should be allowed with well maintain of physical distance and safety precautions while working in field and handling farm machines. Likewise, there should be an immediate rapid response team and agro-scientists availability where farmers should consult and be in touch if any emergency issues arise related to operation and

managing of crops, livestock, machinery and medicines.

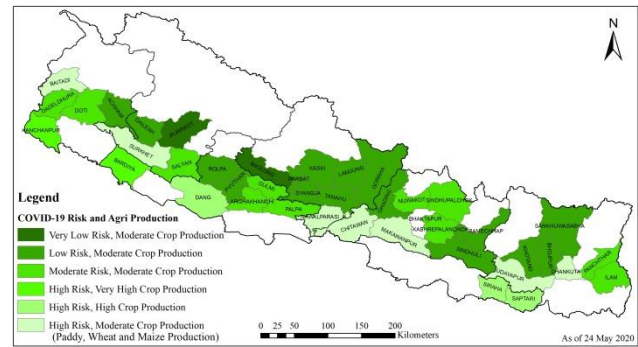


Figure 10. Relaxation of lockdown for agriculture activities

Most of the high fertile crop productive districts occur in very high-risk zone of COVID-19. So, it is not recommended to do agriculture activities to these districts at this current scenario. To counterbalance the deficit of crop production, government have to take immediate actions to the districts such as Bardiya, Kanchanpur, Ilam, Panchthar, Kavrepalanchowk, Sindupalchowk, Bhaktapur, Nuwakot, Palpa, Arghakhanchi, Gulmi, Salyan, Doti and Dadeldhura to make working environment to farmers. The government authorities should encourage farmers towards food crops and away from cash crops at this scenario, which might be very helpful in addressing of food insecurity in coming days.

4. Conclusions and Recommendation

Nepal is a tourism and agriculture-based landlocked country between two rapidly prospering countries of China and India, where the per capita income is estimated US\$ 1034 in FY 2018/19 with 18.7% of population below absolute poverty line (MoF, 2019). Remittance is one of major contributors of Nepalese economy and stability. The overwhelming 62 days of nationwide lockdown, that started on 24 March 2020 and still with uncertainty of when it would end, in such a country would obviously impact everyone especially domestic migrant workers, daily wage labors and farmers, which would cause food shortage, social disturbance and economic recession. So, the crisis demands quick mechanism of risk analysis to modify the modality of lockdown vis-a-vis the necessity to quickly mobilize resources to conduct massive testing and dissemination of results, contact tracing of suspected people and quarantining them along-with well treatment of infected patients. The paper has introduced a GIS platform to visualize spatial temporal distribution of COVID-19 cases in Nepal.

Relaxing the lockdown in the agricultural hotspots across Nepal by taking necessary precautions in moderate to high risk areas has been

even more vital now when many people have left Kathmandu and other cities and have even returned from abroad. They love their motherland more than ever and may want to stay there if some minimum income and survival is ensured. In this light, it appears that Nepal is going through a great opportunity to revitalize and reinstate her latent agro-economy, thereby not to let the national economy collapse or before a huge surge in unemployment and food security would cause a burst and socio-political instability. This would be particularly damaging to Nepal when geopolitical heat and border issues are rising too. Local production, local innovation and self-reliance have been more significant than ever before. Accordingly, agricultural hotspots have been identified nationwide using the data of three significant crops as plotted on GIS platform as well.

The output results of different parameters of risks such as active COVID cases, population density and land entry points of Nepal reveal different levels of risk districts for each parameter simultaneously. The GIS based weighted sum model generated the final output indicating regions ranked from 1 to 5 for decision making on very low risk districts to very high-risk districts for COVID-19 throughout the 77 districts of Nepal. It is noted that the movement of people via air transportation is already closed by government. So, this has not been taken into consideration for analysis. Furthermore, the paper has identified the districts with high crop productivities which are not in very high-risk zone of COVID-19. The analysis was based on active COVID cases, population density and land entry points of Nepal with considering of major food crop (paddy, wheat and maize) only.

The Government of Nepal now should allow farmers to do their agriculture activities within the suggested lesser risk regions with well-maintained social distance and other safety precautions as per WHO standards. This is practicable and needed too. This approach is helpful to alert the authority about the risk level of each of the regions to change the modality of lockdown and restoration of agricultural activities for survival, employment and agro-based economy of Nepal as well. It is encouraging to read some of the initiatives the Ministry of Agriculture has proposed in support of similar recommendation, and this paper should further assist the decision making process of the ministry as well.

The research has some limitations too some of which have been mentioned in the earlier paragraph. Furthermore, the availability of health institutions and their facilities may also provide positive impact in reducing transmission of the disease. The detailed study of risk analysis of a region may also include inter and intra movement of people from

surrounding districts. Some other economic factors such as industries, trade and tourism also need to regulate regularly for economic development. Therefore, it is recommended that we change or include parameters as per necessary analysis in question. The existing scenario of COVID-19 may change time after time. So, the procedure should be regularly updated in a certain time interval to forecast updated risk and modify the modality of lockdown as well.

Acknowledgments: The authors would like to thank the reviewers who provided valuable comments for the improvement in the quality of the paper, and all other helpful hands at different stages of the work

Authors' Contributions: BM carried out modelling and calculations; BM and AM drafted the manuscript; MG supported by literature survey and discussion, SD, RA and SBS contributed for logical discussions, interpretations and critical review.

Conflicts of Interest: The authors declare no conflicts of interest.

Funding: No funding was sought or obtained to conduct this study

Ethical approval

Not required given the nature of the article.

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