Proportionality assessment of rice mills distribution against paddy production in Bangladesh: A GIS spatial analysis

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Abstract

Bangladesh is a populous country whose people mostly depend on rice for their food intake. Paddy is cultivated all over the country and different types of rice mills are established for processing paddy into rice. GIS is a useful tool for data analysis, visualization in maps and selecting sites for various purposes. This study analysed the spatial distribution of paddy production and location of rice mills in Bangladesh, and took a closer look at the proportionality of rice mill distribution against paddy production in the country's different regions. The distributions were shown simply in maps and also with auto-correlation like Moran's I or cluster & outlier analysis and hotspot analysis in both district wise and division wise. The findings revealed that paddy production density was concentrated in the northern areas, especially in north-western areas of the country. Rice mills were also established densely in those areas but the milling capacity against paddy production was much more in those areas. In southern areas there were very few number of rice mills although significant amount of paddy was produced there. Rice mills had not established in the whole country rationally with the paddy production volume.

Keywords: Bangladesh, GIS, paddy production, rice milling capacity, rice mills distribution, spatial analysis

Introduction

Bangladesh is a densely populated country where about 48% of its rural people depend on agriculture for their livelihood and rice cultivation takes the major part (Bangladesh Rice Research Institute (BRRI), 2013). Bangladeshis are commonly characterized of being rice growers and rice eaters. As the principal crop, rice covers about 75% of the total cultivated land area, accounts for 70% of the value of total crop output and constitutes 93% of the total grains produced annually in the country (International Rice Research Institute (IRRI), 1997). It is the staple food of about 150 million people, providing two-thirds of total calorie and about one half of the protein intakes of an average citizen's consumption in the country. This crop contributes one half of the agricultural GDP and one sixth of the national income (Abdullah et al., 2013; Amriah et al., 2015).

Mechanization of rice cultivation particularly minimization of post-harvest losses needs to be considered for combating the future challenges regarding rice issue in Bangladesh (BRRI, 2013). Round the year, paddy is cultivated all over Bangladesh; however, the amount of production varies in different regions. Rice mills for processing paddy into rice are also established regardless of paddy production. Two main varieties (depending upon time of cultivation and harvest time) the Boro, harvested in the rainy season (April-May) produces more than 55% of the total production (International Rice Research Institute (IRRI), 1997). Through GIS, both spatial and non-spatial data can be analyzed. While spatial distribution of paddy production and capacity of rice mills are done by spatial analysis, spatial distribution of milling capacity normalized by paddy production volume is observed to check the proportionality in distribution of rice mills all over Bangladesh.

Study area

Bangladesh is a small country with 147,570 km^2 (Tasnuba & Asif, 2014), which spread in 20°34″to 26°38″ North Latitude and 88°01″ to 92°41″ East Longitude. It is a south Asian country having an area of 1 lakh and 47 thousand square km. It is almost surrounded by India in three sides except a small bordering portion in south eastern side with Myanmar. The Bay of Bengal lies at the south of Bangladesh. The country is low-lying riverine land traversed by the many branches and tributaries of the Ganges and Brahmaputra riverswhich are taking about 6% of its total area. It is almost a plane land except some hilly areas in the eastern part.

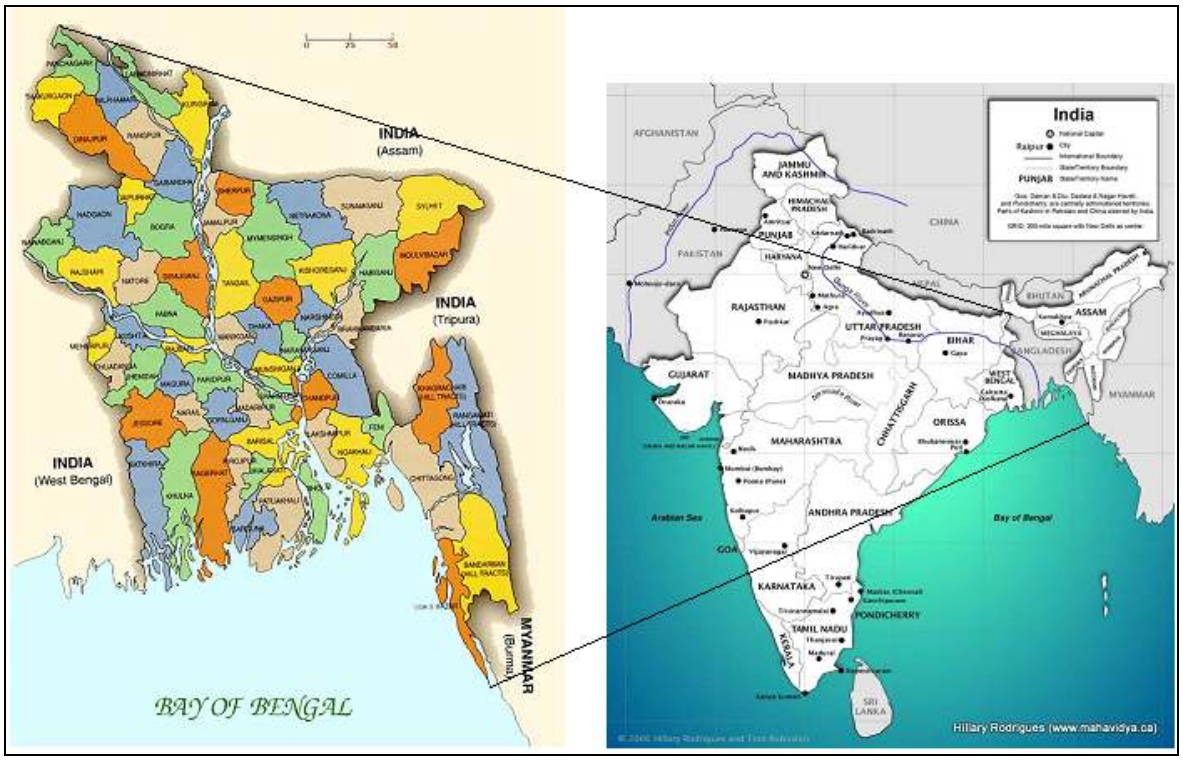

Figure1. *Study area of Bangladesh*

Methodology

Worldwide most popular GIS software ESRI's ArcGIS10.1 was used for doing data analysis and presentation in maps (Osama et al., 2008). Paddy production data of Aman and Boro season in the year 2013 was collected from the Department of Agriculture Extension (DAE) of Bangladesh. Information of rice mill was taken from the Department of Food. Simple Symbology operation is used to show the spatial distribution of paddy production, production density, rice milling capacity and capacity against paddy production in districts and also in divisions. Besides this Moran's I and Hot Spot analysis are also done to see the auto correlation of both paddy production and rice milling capacity taking districts as unit.

Result and discussion

The result presentation starts with preparing maps exposing the scenario of district wise annual paddy production volume, number and crushing capacity of existing rice mills all over the country. Then the maps of these same criteria are exposed for divisions too. Observations in these maps are described in words.

Maps of spatial auto-correlation analysis like Cluster and Outlier Analysis and Hot Spot analysis are presented and described. Paddy production, production density, over all rice milling capacity and millingcapacity against paddy production volume all over Bangladesh are analyzed.

District wise paddy production all over Bangladesh

In the map in Figure 2 it is seen that the top four paddy producing districts of the country are Mymensingh, Naogaon, Dinajpur and Bogra followed by Jessore, Rangpur, Sunamganj, Netrakona and

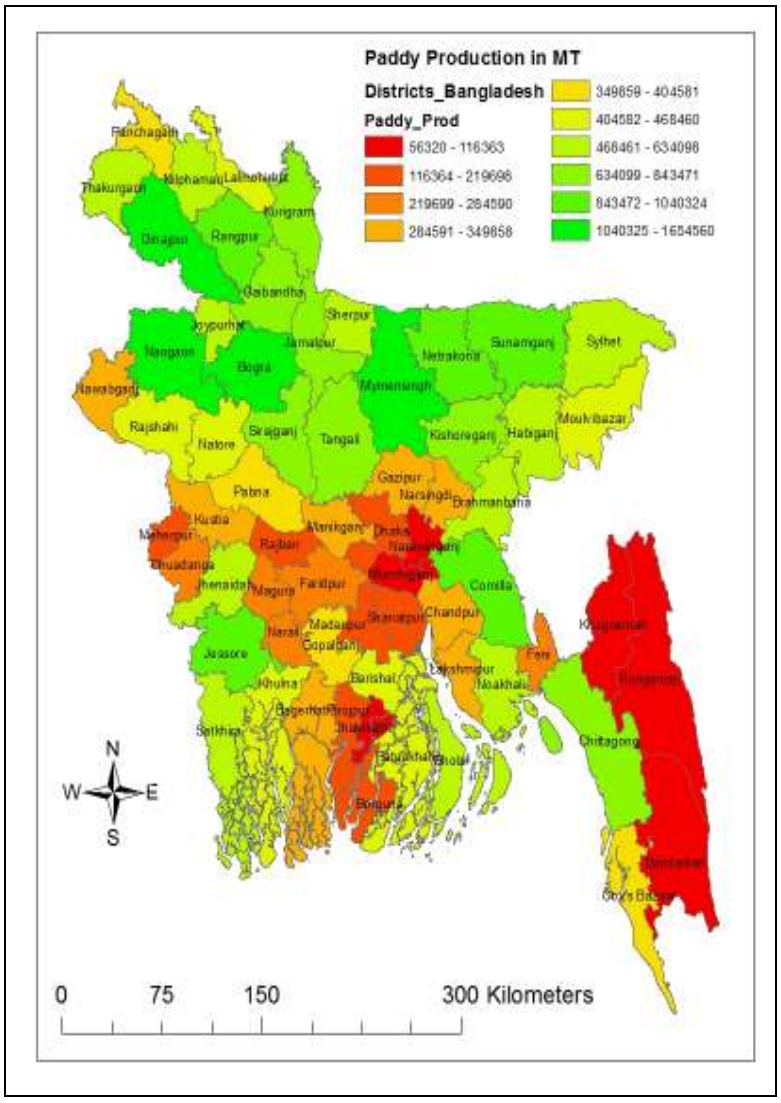

Figure 2. *District wise paddy production all over Bangladesh*

Brahmanbaria. Least amount of paddy is produced in the districts of Narayanganj, Munshiganj and Jhalokathi in plain land along with three hilly districts; Bandarban, Rangamati and Khagrachari. It is seen in the map that paddy grows more in the northern part of the country than the southern part.

District wise paddy production density all over Bangladesh

From the map in Figure 3 it is observed that among all the districts of the country Bogra along with its neighbouring Joypurhat district is having the highest density in paddy production. Three hilly districts

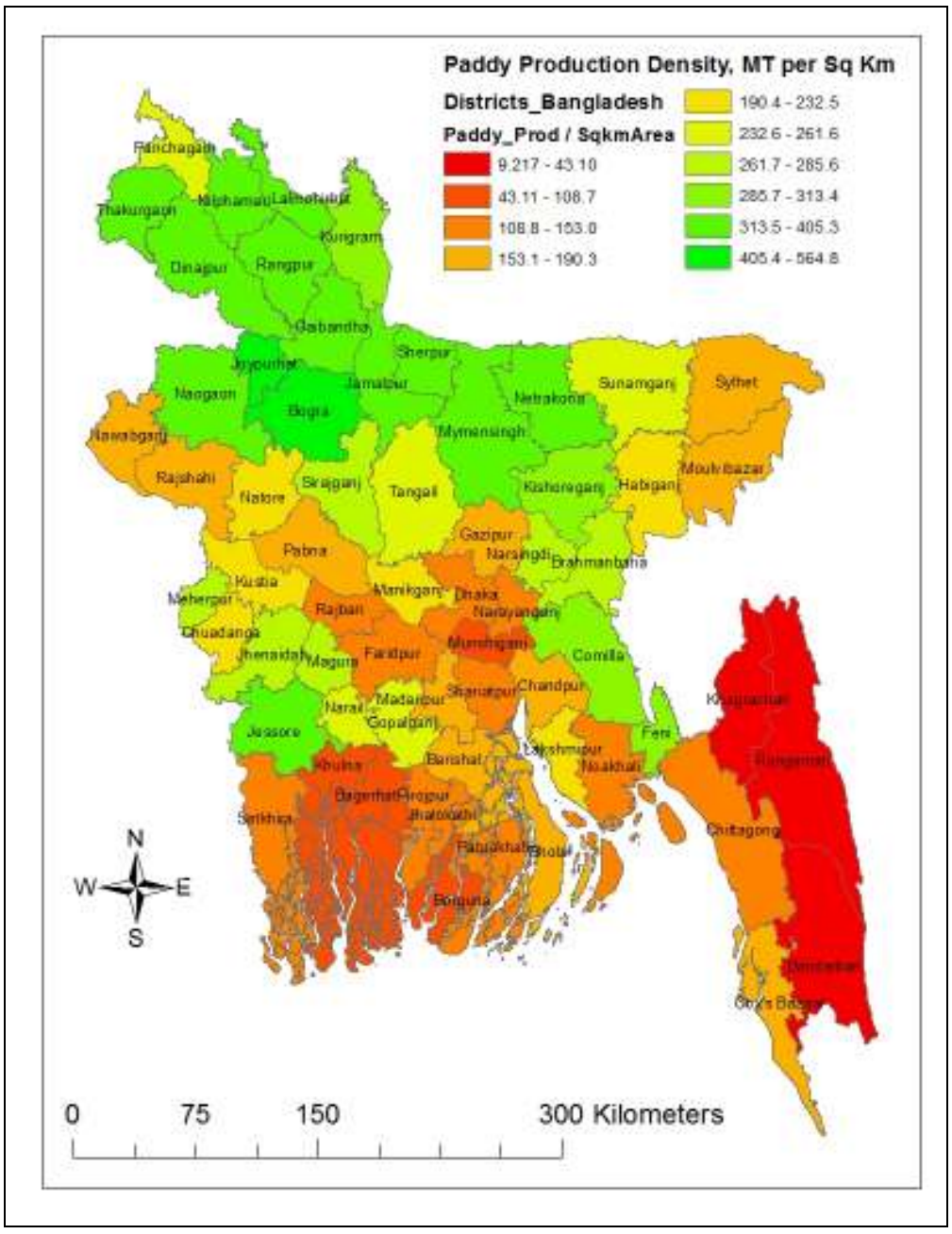

Figure 3. *District wise paddy production density all over Bangladesh*

Khagrachari, Rangamati and Bandarban have the lowest density of paddy production. Overall production density is higher in Northern areas than that in Southern part. But paddy production density in Jessore district under South-Western division Khulna is much higher compared with the neighbouring districts.

Division wise paddy production distribution all over Bangladesh

The map in Figure 4 shows that the highest amount of paddy is produced in Dhaka division followed by Rangpur and Rajshahi division. Barisal division is at the bottom of paddy production ranking. Sylhet and

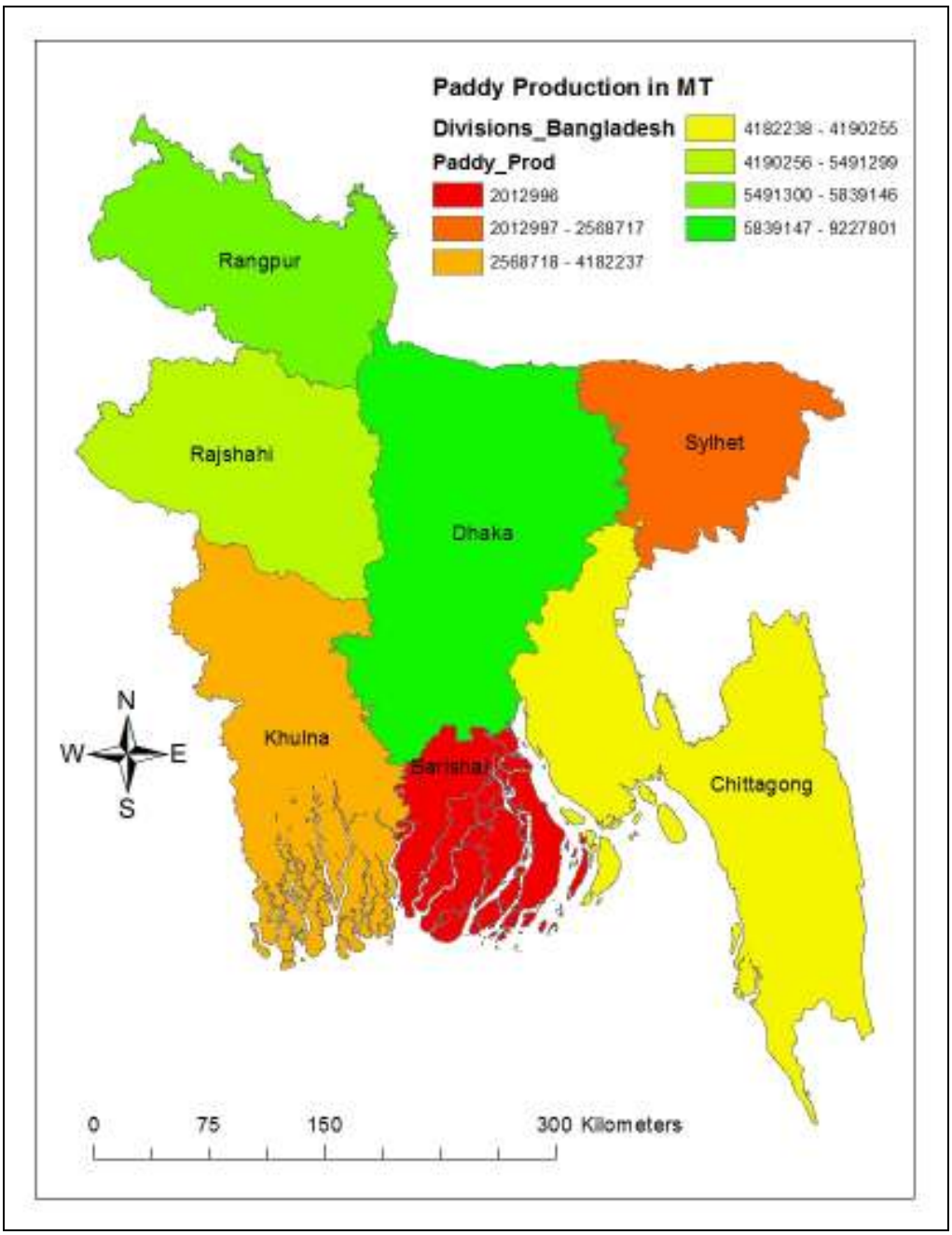

Figure 4. *Division wise paddy production all over Bangladesh*

Khulna divisions are second and third lowest respectively in paddy production. Chittagong division stands at the midst of the ranking of production volume.

Division wise paddy production density all over Bangladesh

It is visible on the map in Figure 5 that the Northeast division of the country, Rangpur has the highest density of paddy production and Rajshahi division follows it. Chittagong division suffers most with paddy

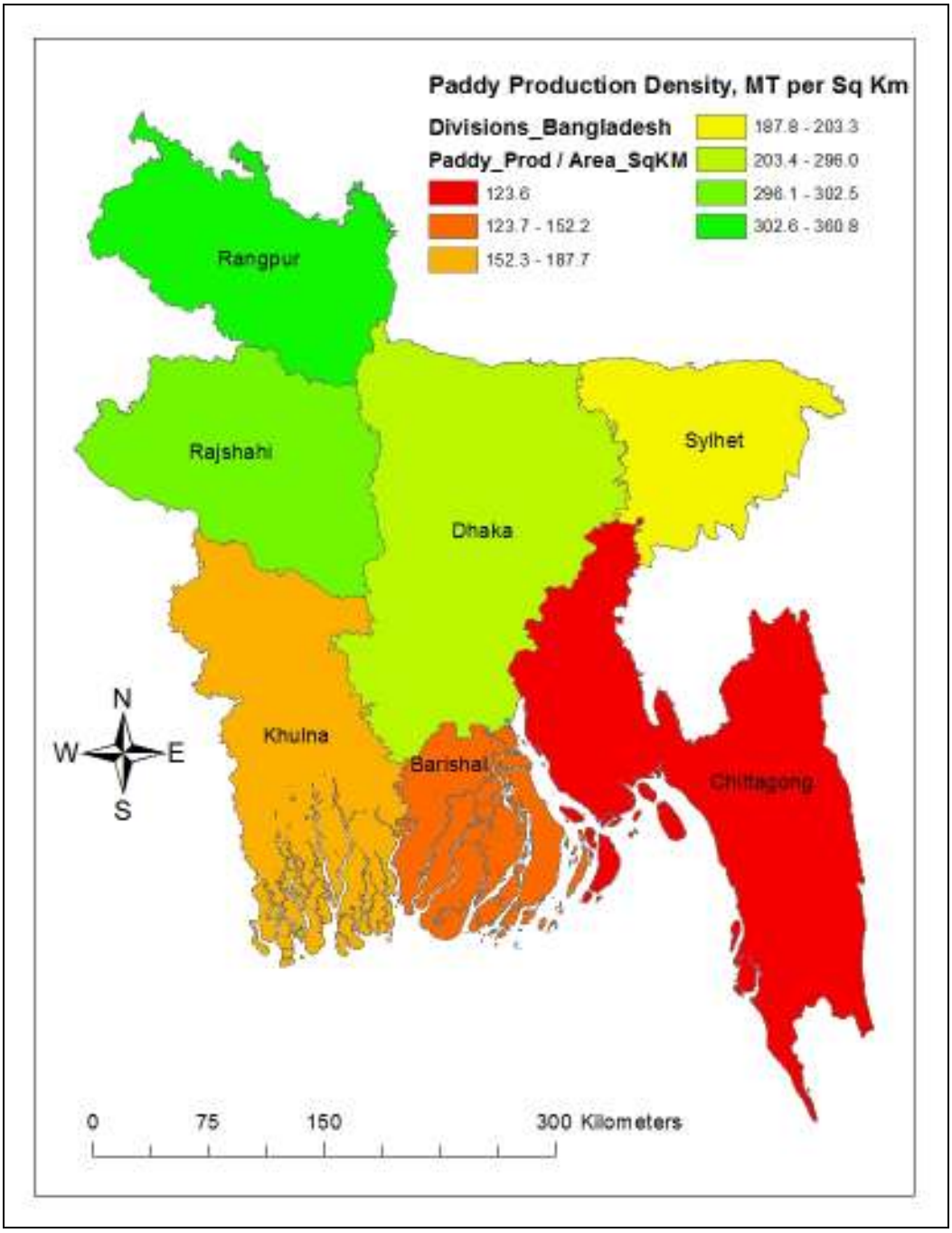

Figure 5. *Division wise paddy production density all over Bangladesh*

production density. Density of paddy production increases from Barisal to Khulna and then to Sylhet and Dhaka division.

District wise rice mill distribution all over Bangladesh

The crushing capacity of parboiled rice mills are categorized in 10 levels as shown on the map in Figure 6. Dinajpur, Thakurgaon, Naogaon and Bogra districts have the highest crushing capacity followed by

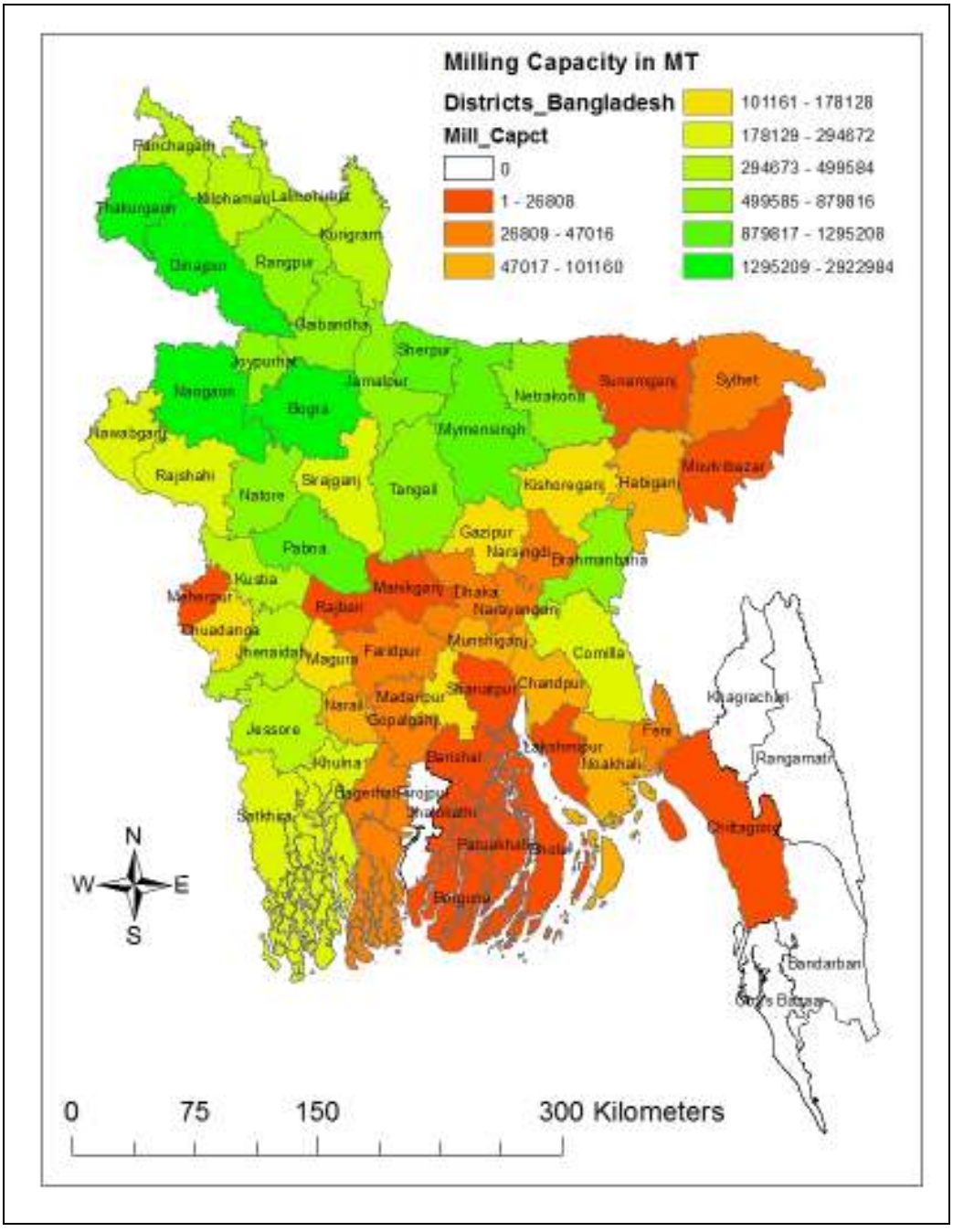

Figure 6. *District wise parboiled rice milling capacity all over Bangladesh*

Pabna, Mymensingh and Sherpur districts. There is no rice mill to produce parboiled rice in the districts of Cox's Bazaar, Bandarban, Rangamati, Khagrachari and Pirojpur.

Division wise rice mill distribution all over Bangladesh

From the map in Figure 7 it is clear that Rangpur division has the maximum capacity of parboiled rice mills followed by Rajshahi and Dhaka division. Barisal Division has the lowest crushing capacity and Chittagong division is the second lowest. Crushing capacity increases in Sylhet, Khulna and Dhaka divisions sequentially.

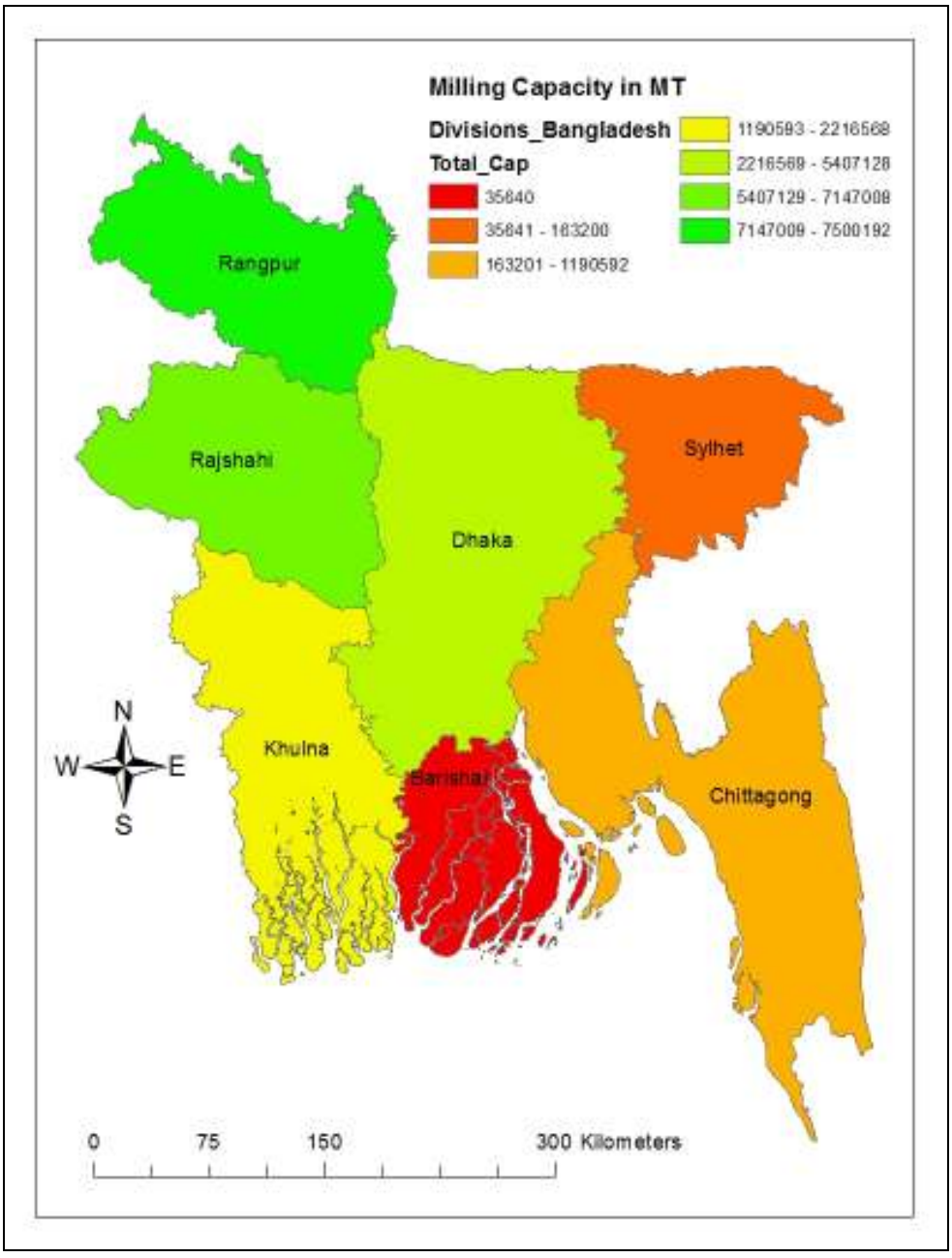

Figure 7. *Division wise parboiled rice milling capacity all over Bangladesh*

District wise milling capacity normalized by paddy production

It is seen in the map in Figure 8 that Dinajpur, Thakurgaon and Pabna districts are having the highest ratio of milling capacity to annual paddy production. Naogaon, Bogra, Joypurhat, Natore, Kustia, Sherpur, Brahman Baria and Jamalpur districts have a ratio more than 1.00 i.e. having excess mills in those areas.

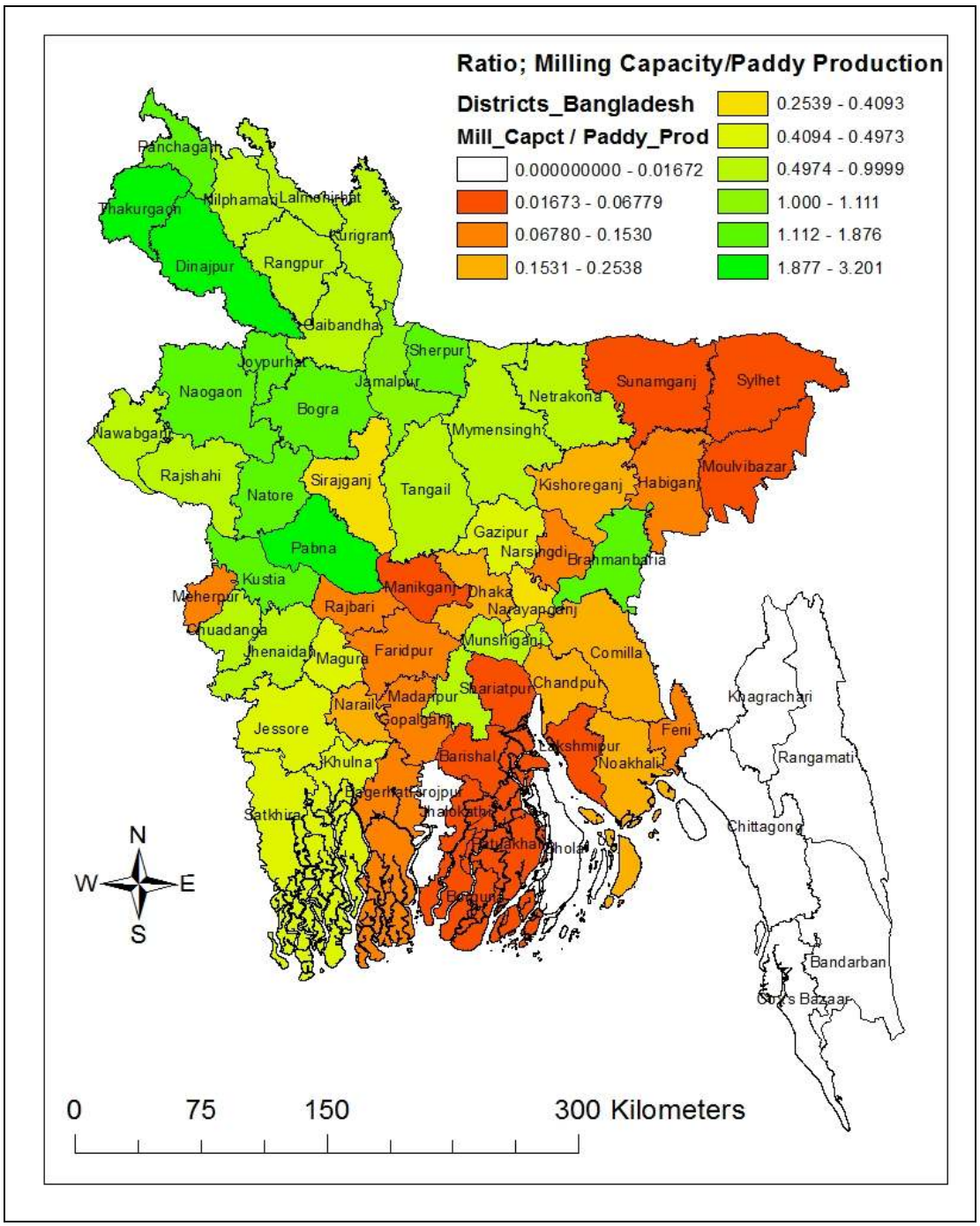

Figure 8. *District wise rice milling capacity normalized by paddy production*

The ratio is 0.00 in the districts of Cox's Bazaar, Bandarban, Rangamati, Khagrachari and Pirojpur, as there is no rice mill to produce parboiled rice in those areas.

Division wise milling capacity normalized by paddy production

The map in Figure 9 shows that although Rangpur division has the highest total crushing capacity of the mills, the ratio of milling capacity to annual paddy production is the highest in Rajshahi division.

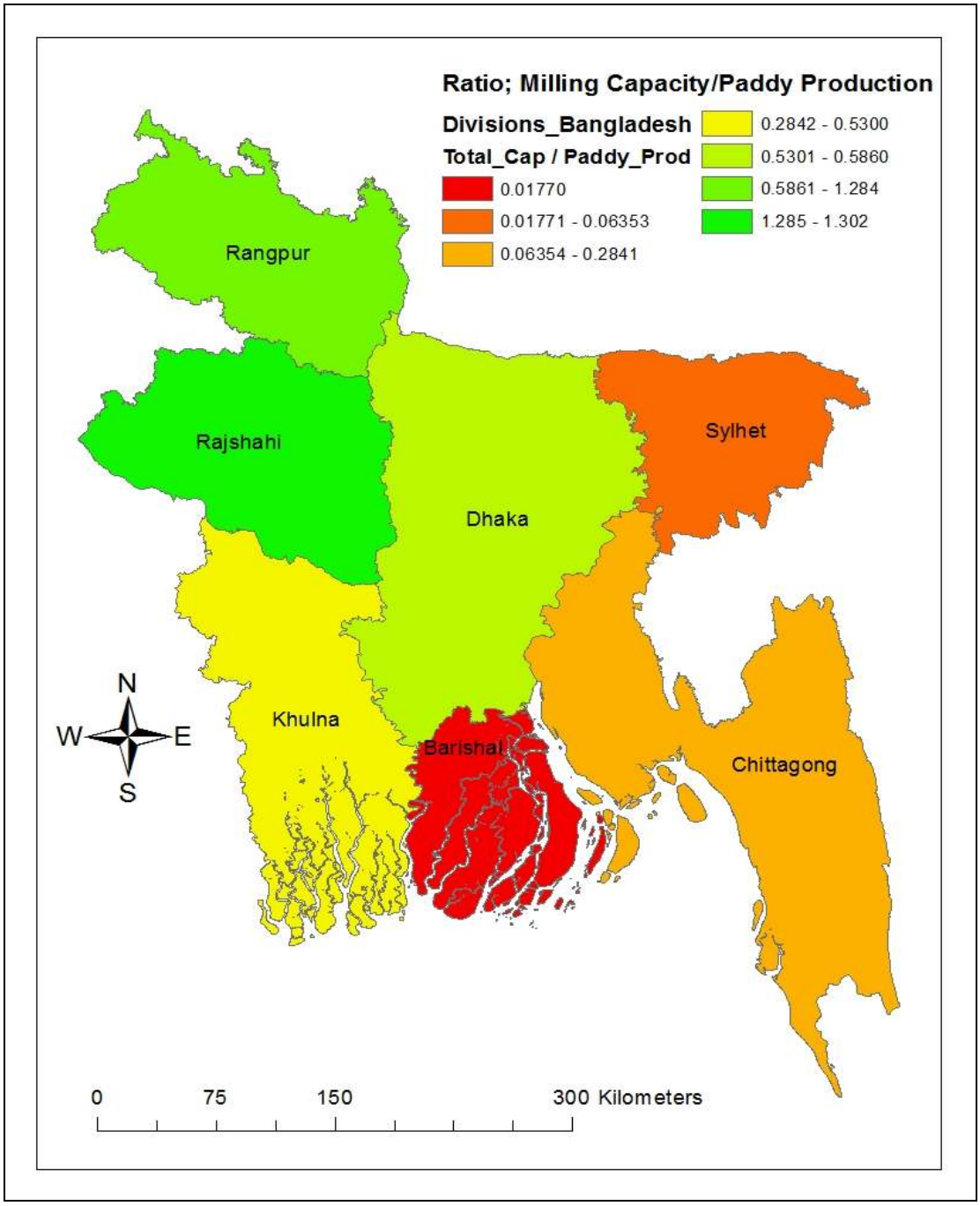

Figure 9. *Division wise rice milling capacity normalized by paddy production*

Both the divisions have ratio more than 1.00, meaning that there are excessive number of rice mills than the requirement in those areas. Barisal and Sylhet divisions stand serially at the bottom of ratio ranking order.

Spatial auto-correlation Moran's I and hot spot Analysis

Moran's I measures spatial auto-correlation based on feature locations and attribute values. Given a set of weighted features, identifies statistically significant hot spots, cold spots, and spatial clusters or outliers by using the Anselin Local Moran's I statistics. Hot Spot Analysis identifies statistically significant hot spots and cold spots of a given set of weighted features using the Getis-Ord G statistics.The G statistics measures the degree to which large or small values of a variable clusters.

Clusters and outlier analysis of paddy production

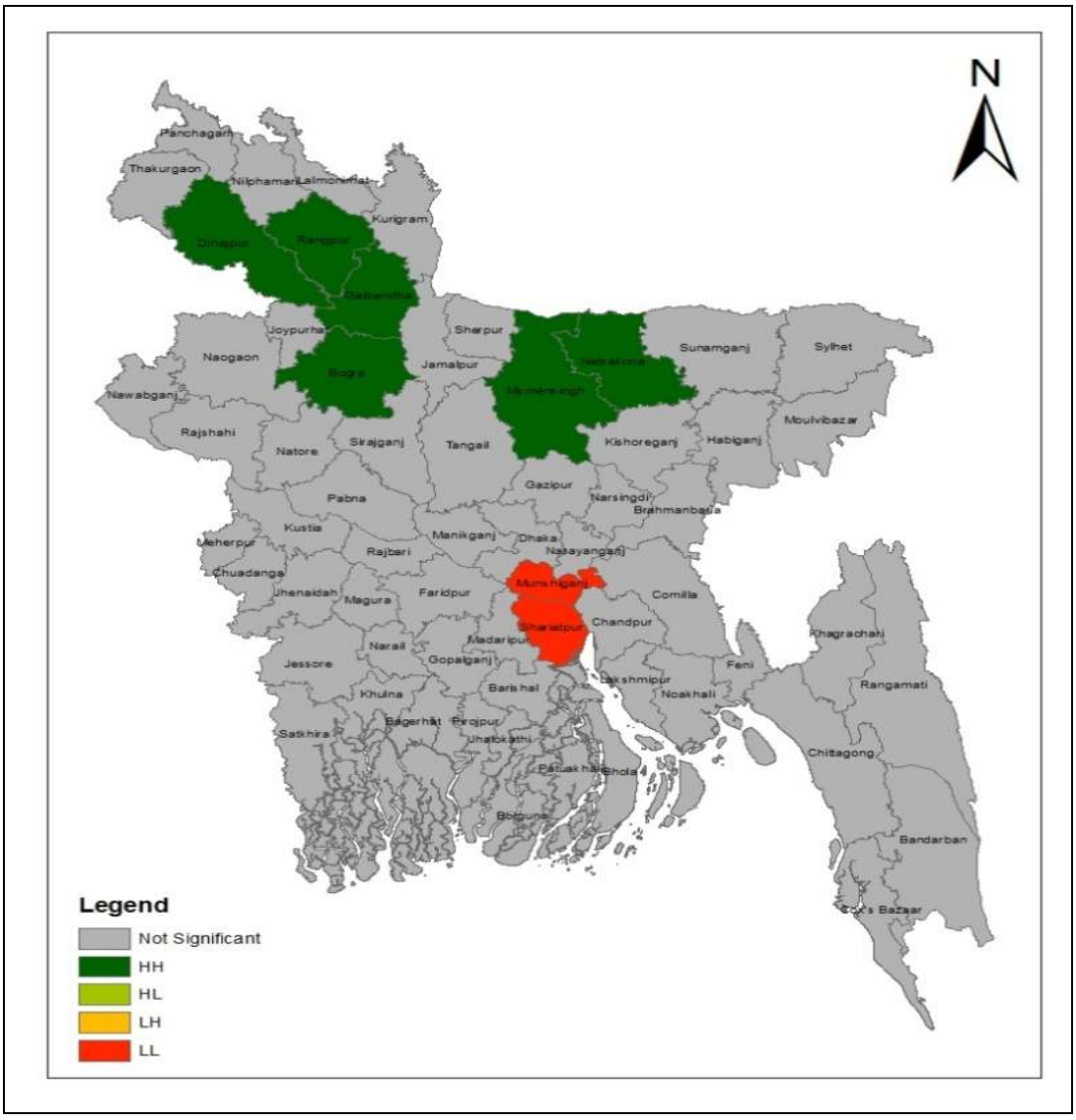

Figure 10. *Clusters and outlier of paddy production in Bangladesh*

The map in Figure 10, generated through the analysis shows that 6 districts named Dinajpur, Rangpur, Gaibandha, Bogra, Mymensingh and Netrakona are adjacent with high paddy production zones i.e. HH (High-High) auto-correlation. Munshiganj and Shariatpur districts are surrounded with areas those produce low amount of paddy i.e. LL (Low-Low) auto-correlation. There is no remarkable HL (High-Low) or LH (Low-High) auto-correlation. Therefore auto-correlation in other areas is shown as insignificant.

Hot spot analysis of paddy production

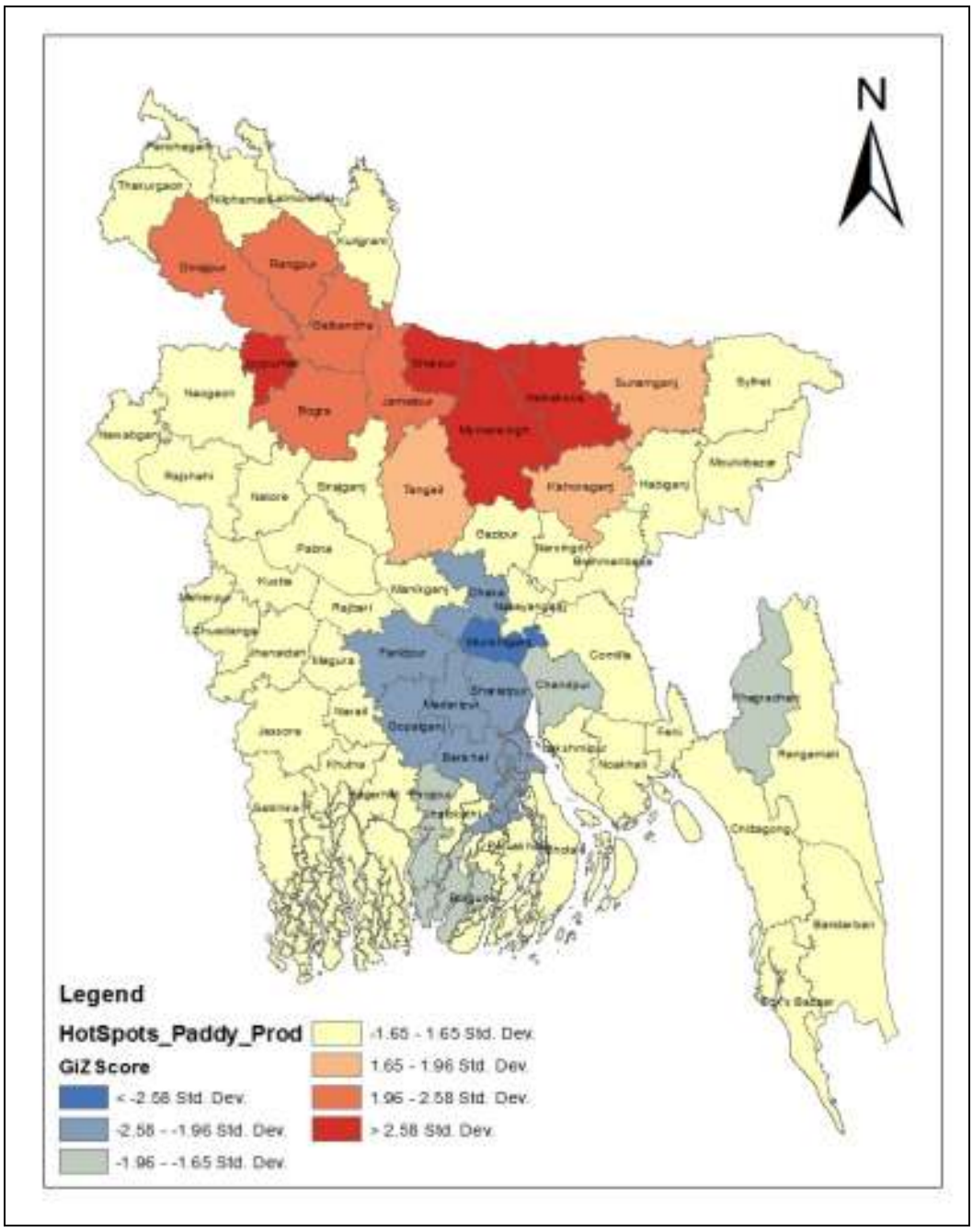

Figure 11. *Hot spots of paddy production in Bangladesh*

The map generated through Hot Spot Analysis, as displayed in Figure 11, reflects the clustered areas. Mainly Northern districts show clustering of paddy production. Joypurhat, Sherpur, Mymensingh and Netrakona are mostly clustered with z-value more than 2.58 i.e. at 99% confidence level. Munshiganj district is clustered at the lowest production zone having z-value less than -2.58 i.e. at 99% confidence level.

Cluster and outlier analysis of paddy production density

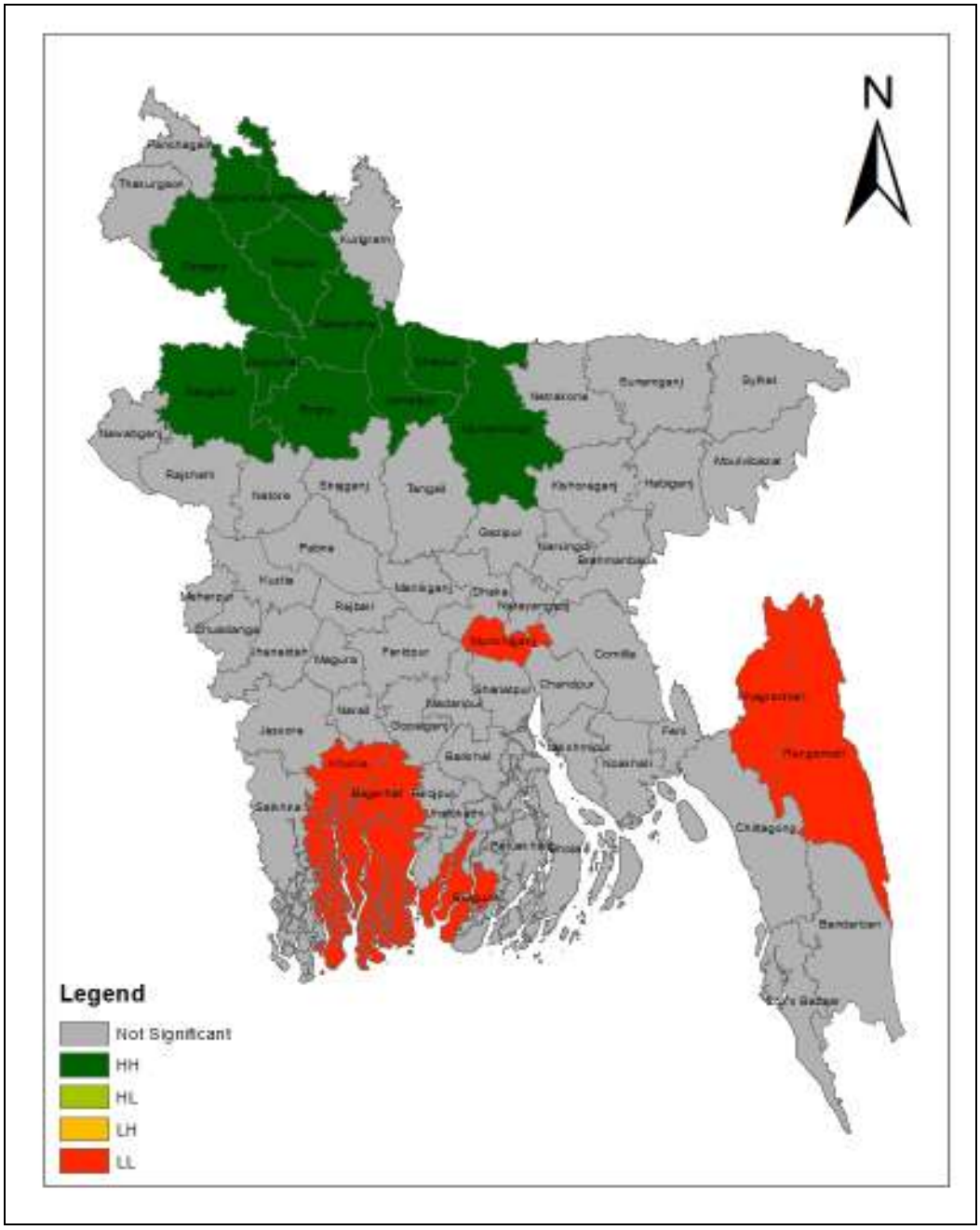

Figure 12. *Cluster and outlier of paddy production density in Bangladesh*

The density of paddy production is seen concentrated in North-Western corner of the country as shown in the map in Figure 12. Dinajpur, Nilphamari, Rangpur, Gaibandha, Joypurhat, Naogaon, Bogra, Jamalpur, Sherpur and Mymensingh districts show HH i.e. adjacency of high density of paddy production. Low density exists in the Eastern hilly areas, in South-Western Khulna zone and also in the central area in Munshiganj district. There is no significant HL or LH adjacency.

Hot spot analysis of paddy production density

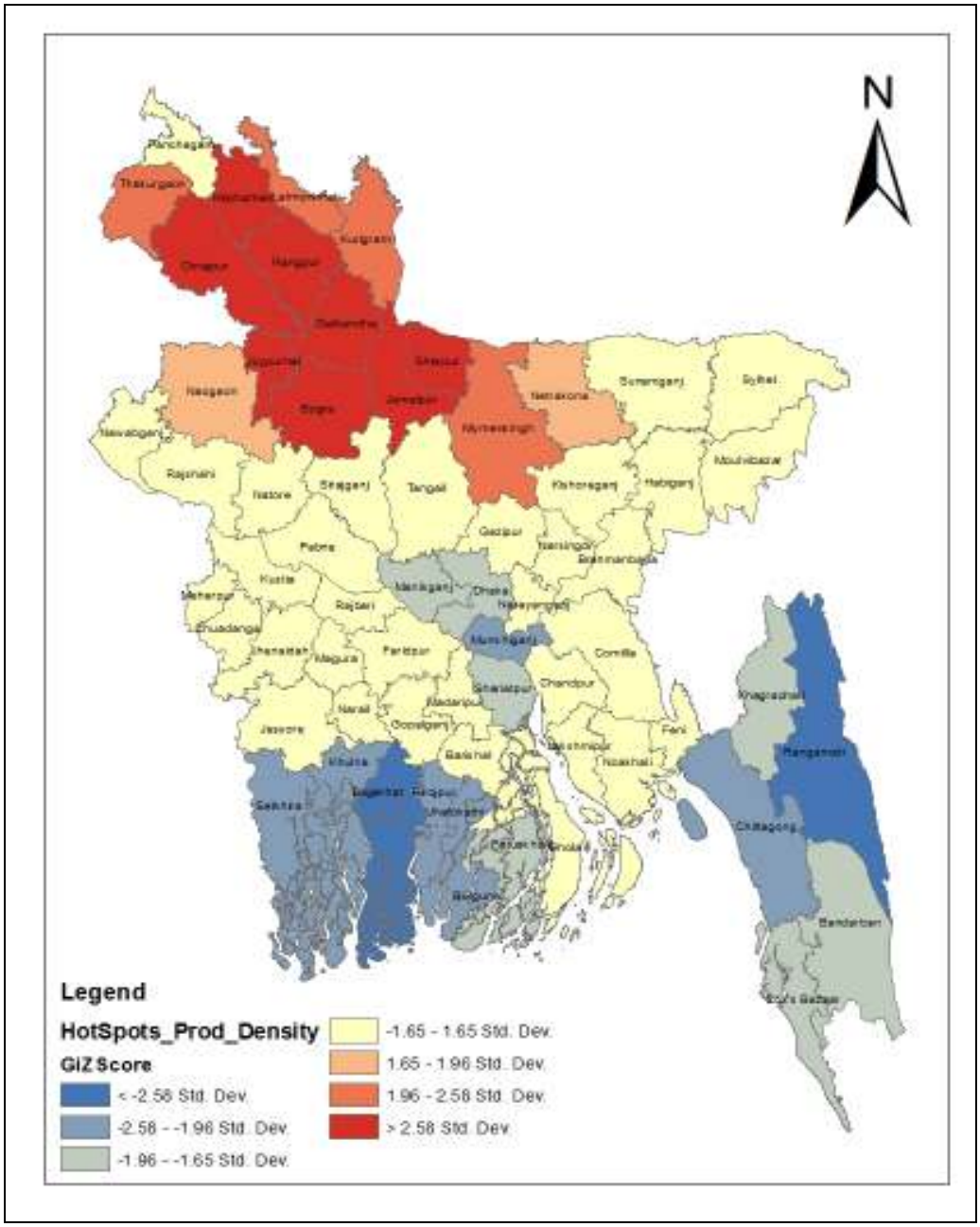

Figure 13. *Hot Spots of Paddy Production Density in Bangladesh*

The map in Figure 13 shows that North-Western districts as Dinajpur, Nilphamari, Rangpur, Gaibandha, Joypurhat, Bogra, Jamalpur and Sherpur show high spatial auto-correlation of thick paddy production density at 99% (z-value>2.58) confidence level. Thakurgaon, Lalmonirhat, Kurigram and Mymensingh districts are at 95% (z-value>1.96) confidence level. The hilly district Rangamati and Bagerhat district of Khulna zone show high spatial auto-correlation of thin paddy production density at 99% (z-value<-2.58) confidence level.

Cluster and outlier analysis of rice milling capacity

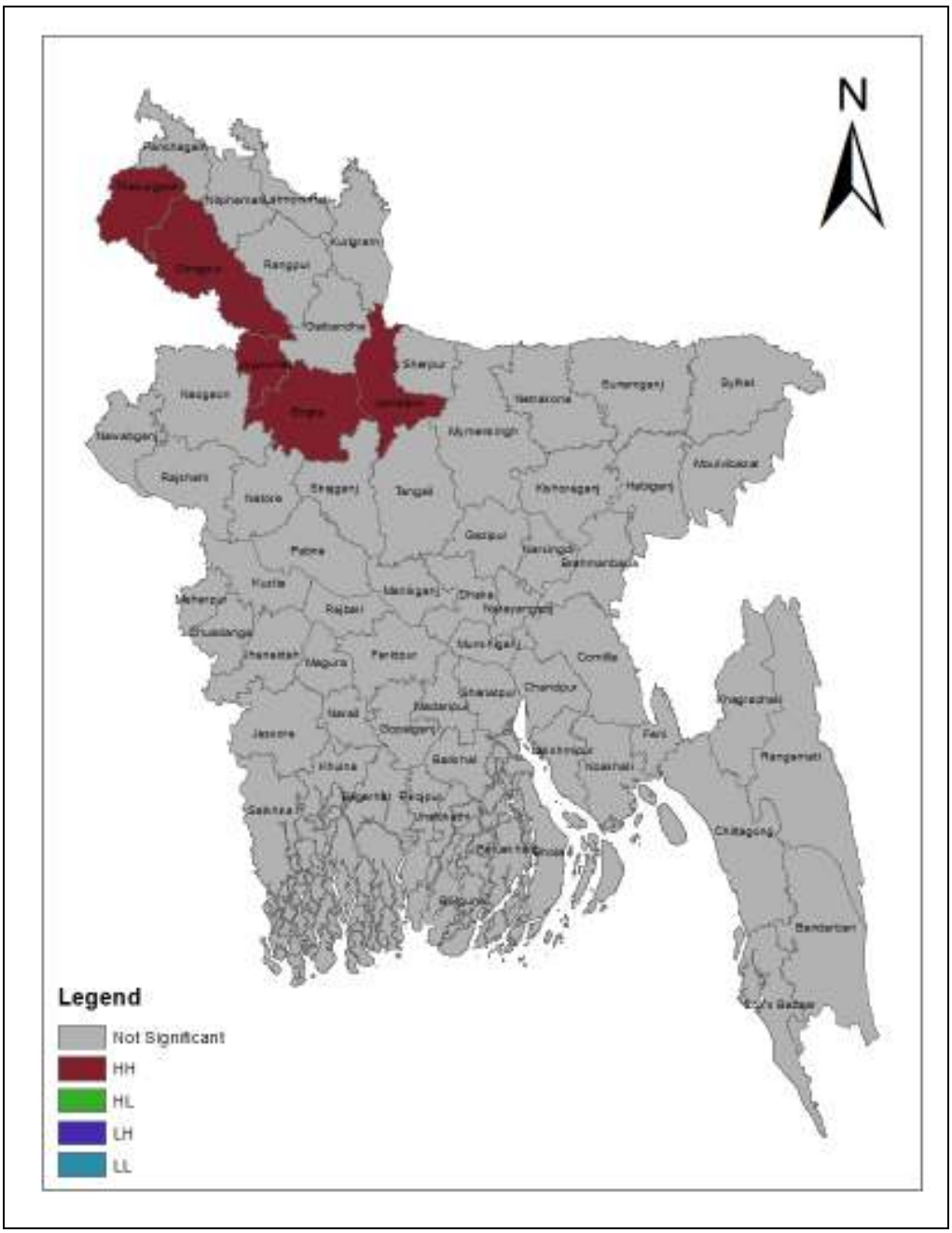

Figure 14. *Cluster and outlier of rice milling capacity in Bangladesh*

As seen in the map in Figure 14, Dinajpur, Thakurgaon, Joypurhat, Bogra and Jamalpur districts show HH spatial auto-correlation of milling capacity. There exists no LL, HL and LH auto-correlation of milling capacity of rice mills in the country. It is clear from this analysis that rice milling capacity is concentrated or clustered in a narrow region of the country.

Hot spot analysis of parboiled rice milling capacity

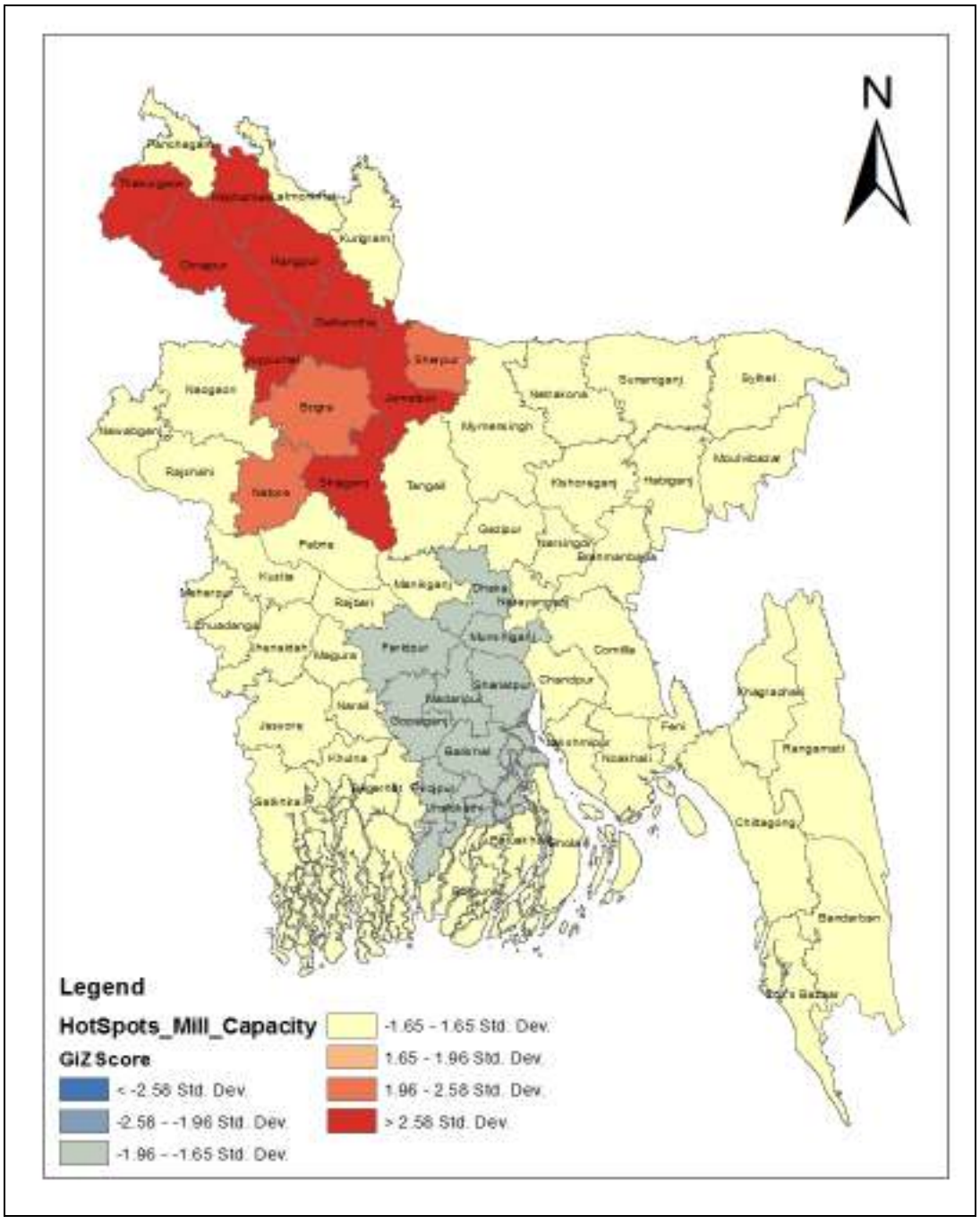

Figure 15. *Hot spots of rice milling capacity in Bangladesh*

The map in Figure 15 shows that Dinajpur, Thakurgaon, Nilphamari, Rangpur, Gaibandha, Joypurhat, Bogra, Jamalpur and Sirajganj districts are in high positive spatial auto-correlation of parboiled rice milling capacity at 99% (z-value>2.58) confidence level. Bogra, Sherpur and Natore districts are at 95% (z-value>1.96) confidence level. There is negative spatial auto-correlation of parboiled rice milling capacity neither at 99%(z-value<-2.58) confidence level nor at 95% (z-value<-1.96) confidence level.

Conclusion

This distribution was mapped in district level as well as in division level. Along with annual paddy production (Aman and Boro) the density of paddy production was also mapped in district and division levels. The spatial distribution of paddy production shows that the North-Western districts of the country produce more paddy than the South-Eastern ones. Dhaka division produces the highest amount of paddy while Barisal division produces the lowest. However, the production density is the highest in Rangpur division and the lowest in Chittagong division. There is high clustering of paddy production density in Northern districts like Mymensingh, Jamalpur and Sherpur of Dhaka division; in Joypurhat and Bogra of Rajshahi division and in Gaibandha, Rangpur, Dinajpur and Thakurgaon of Rangpur division. Low paddy production clustering exists in three hilly districts of Chittagong division along withMunshiganj and Narayanganj districts of Dhaka division.

To see the spatial distribution of existing rice mills, instead of the number of mills, the total capacity of parboiled rice producing mills were mapped in district and division levels in Bangladesh. Maps were prepared showing annual milling capacity and normalized by annual paddy production as well. Most of the rice mills for producing parboiled rice are established in Northern districts. The overall capacity of the rice mills in Rajshahi and Rangpur division is more than that required. Most of them are normal husking mills. The number and capacity of the rice mills in Southern part of the country specifically in Barisal division is inadequate.

Observing such non-uniform distribution of rice mills with respect to paddy production, it can be assumed that, either huge amount of paddy is to be transported from one area to another area for processing or many of the mills in some areas cannot keep on operation all the year round to utilize their full capacity. Or a good amount of paddy may still being processed manually or with simple crushers in rice mill deficit areas. Either of the cases is a cause of inefficiency of paddy processing operation in the country.

From the findings of district level analysis, businessmen can get clues for new investment to upgrade or shift their mills. The areas where milling capacity is comparatively high will not give room for newcomers; hence, the existing millers should go for upgrading their mills to automatic ones. But the areas where milling capacity is not proportionate with paddy production have much potentiality to make new investment rice mills. The existence of clustering and agglomeration economy in rice milling sector is also detected through this analysis, so investors have to consider this phenomenon.

Geographic Information System tool is used in many different ways for analysing spatial or non-spatial data and visualizing the findings in maps. Spatial distribution of paddy production and rice mills in whole Bangladesh are discussed and shown in maps. Spatial auto-correlation of these items through Cluster & Outlier and Hot Spot analysis is also done, shown in maps and discussed.

Limitations of the study

The following are the specific limitations of the study:

a) In the total production of paddy, the main two crop seasons, Boro and Aman production data were considered. The third crop season Aus was not included although it also has some contribution to the total production.

b) The milling capacity of only parboiled rice producing mills was considered although there were a number of Atap (white or plain rice) producing mills all over the country. There was no documented information of small paddy huskers working from door to door of the farmers in the villages.

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