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Trend Analysis and Prediction of Cropped Area of Bangladesh

Md. Akter Faruk Fuad [a*], Md. Hasan Sofiur Rahman [b], Fatema Tuz Johara [a], Kaniz Fatima Jui [c] and Umme Munmun Ashrafi Flora [d]

[a] Masters' Program in Environmental Sciences, University of Tsukuba, Ibaraki 305-8577, Japan.
[b] Scientific Officer, Bangladesh Institute of Nuclear Agriculture, Bangladesh.
[c] Masters' Program in Agricultural Economics, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh.
[d] Masters' Program in Business Administration, ASA University, Bangladesh.

Authors' contributions

This work was carried out in collaboration among all authors. Author MAFF performed the conceptualization, methodology, analysis, investigation, data curation, writing- original draft preparation. Authors MAFF, MHSR, FTJ, KFJ and UMAF did the writing-review and editing. Authors MHSR, FTJ, KFJ and UMAF supervised the work. All authors read and approved the final manuscript.

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ABSTRACT

This systematic review is an effort to examine the trajectory of cropped area in Bangladesh using secondary data. This qualitative and descriptive analysis was conducted using numerous government's Statistical Yearbooks. The study revealed that single cropped area was shrinking, whereas multiple cropped area was flourishing. The expansion of areas was observed in both cereals and vegetables. Another significant finding was that a sharp growth was seen in both the net and gross cropped area. The cropping intensity was also gradually rising, which would allow practicing modern technologies to utilize existing and accredited areas. Further studies are required

**Corresponding author: E-mail: fuad.ag2306@gmail.com;*

to understand the accredited farm areas in terms of policy-related factors. The study's results offer valuable insights for decision-makers in Bangladesh to preserve and utilize the farmland resources sustainably.

Keywords: Cropped area; cereals; vegetables; cropping intensity; Bangladesh.

1. INTRODUCTION

The economy of Bangladesh relies heavily on agriculture, as it serves as the primary source of food security and facilitates the country's progression towards middle-income status [1]. Bangladesh holds the position of the third-largest producer of vegetables and rice, as well as the seventh-largest producer of potatoes worldwide [2]. To meet consumers' demand for more diversified products, producers are shifting their farming practices by focusing on more profitable production [3]. The trend analysis and prediction of cropped area is a hot topic in the agricultural sector, especially in Bangladesh. The concept of cropped area refers to the specific geographic region that is deemed suitable for agricultural production. However, the authors have identified a comprehensive empirical research gap on this topic in Bangladesh. Therefore, this study intends establish a better understanding of trend analysis and prediction of cropped area in Bangladesh for responsive policy and practices.

The study does not include particular policy elements that go beyond a thorough long-term foresight exercise in order to attain an ideal future but rather, it upholds an advocacy paradigm. Thus, this study emphasizes the statistical variations in the cropped area of cereals and vegetables, as well as cropping intensity, since 2010.

2. MATERIALS AND METHODS

2.1 Study Area

This study conducted in Bangladesh, a South Asian nation, between the latitudes $20^0 34'$-$26^0 38'$ N and the longitudes $88^0 51'$-$92^0 41'$ E, covering an area of 147,570 km^2. The national territory is on one of the largest and most complex deltas in the world, where the Ganges-Brahmaputra and Meghna (GBM) rivers enter the Bay of Bengal [4]. The GBM trans-boundary river basin flows through the central part of the country. It's agriculture accounts for about 14% of its GDP and employs 40.6% of the workforce [5]. The expanding population is driving up the demand for food, and this circumstance puts pressure on 16,562,974 farm households [6].

2.2 Data Collection

This study used the annual agricultural statistics yearbook produced by the Bangladesh Bureau of Statistics (BBS). The BBS works under the planning ministry and serves as a scientific basis for formulating appropriate guidelines, including strategic plans for the advancement of Bangladesh. The BBS compiled annual and periodic sample surveys under the FAO guidelines [7].

Simultaneously, most of the available literatures on Bangladesh's cropped area were carefully examined and used systematically for this review. This study used various popular and relevant websites, such as Google Scholar, Web of Science, AGRIS, SCOPUS, Academic Search, WorldWideScience, etc., to conduct a comprehensive web search. Finally, the collected data are processed, consolidated, and published, so that policymakers, analysts, academics, educators, and other researchers can use it as a reference tool.

2.3 The Analytical Framework

The administrative structure of Bangladesh comprises 64 districts, 495 sub-districts, and 4,571 municipalities. The BBS uses 10,348 clusters as sampling frames, each of which represents 2.02 hectares of land. The sub-districts are treated as strata, while the districts are considered evaluation domains. Clusters are allocated proportionally to size and limit the number of clusters in a district is 150 or more. At least one or more clusters are selected from each municipality. Clusters are formed from cadastral plots listed in the land register. The BBS keeps and updates a list of farmers whose fields are in each cluster, and the field workers visit the clusters four times a year to collect pertinent agricultural data. The cropped area is estimated as:

The district's cropped area for a crop = The district's effective cropped area × Cropped area ratio of that crop in the district

The district's effective cropped area = The area of the district - The area not used for agricultural purposes.

The district's cropped area ratio = The total cropped area of the plots in the cluster for the districts ÷ The total area of the respective clusters for the district.

Single cropped area means a given area where only one particular crop is grown in a year, where double cropped area represents a given area where two particular crops are grown in a year. Similarly, a given area where three particular crops are grown in a year called triple cropped area, and quadruple cropped area means a given area where four particular crops are grown in a year. The physical extent of cropped area, on which particular crops sown and harvested in a year, but that area is counted only once is called net cropped area. The cumulative size of net cropped area in a given year is gross cropped area (GCA), and it is the maximum physical area cultivated in a year. The gross cropped area in a year is estimated as:

Gross cropped area = Single cropped area + (2×Double cropped area) + (3×Triple cropped area) + (4×Quadruple cropped area)

The ratio of "gross cropped area" to "net cropped area" in a year is known as cropping intensity, and it is typically stated as a percentage. Cropping intensity describes how many crops harvest cycles per year in a given area. The BBS collects the data nationally and conducts this estimation for each district and year in Bangladesh [7].

This paper explores the various models and algorithms developed for agriculture, focusing particular on prediction and forecast methodologies. Ersoy and Gümüş, [8] used time series analysis to forecast profits in crop production. Rana [9] employed a fuzzy time series method to analyze crop-yield data. Niyigaba and Peng [10] used the grey model and ARIMA methods to forecast agricultural production. Zhichkin et al. [11], Hassan (2018), Kazmi and Rasul [12] applied linear regression method for agricultural land prediction. Hrytsiuk and Babych [13] studied the predicting profits of grain production through the application of regression analysis and fuzzy simulation principles. To predict the wheat production, Safa et al., [14] used an artificial neural network (ANN) approach.

This study carried out through a qualitative analysis of descriptive literature in Bangladesh. It employed the linear regression method to predict future trends of cropped area. The utilization of this approach is prevalent in Bangladesh for agricultural prediction to facilitate planning, resource management, economic development, and social protection. The following equation was used to analyze the data with the aid of MS Excel and SPSS software.

$$y = a+bx+e$$

Where,

y represents response variable
x represents explanatory variable
a represents intercept
b represents the regression coefficient
e represents the error term

3. RESULTS AND DISCUSSIONS

3.1 Scenario of Single, Double, Triple and Quadruple Cropped Area

Bangladesh's agricultural sector is diversified, with about 8.7 million hectares of cropped area [15]. Typically, the cropped area is classified under the frequency of crops grown there, and it is crucial to estimate the overall cropped area. This study examined the changes in the size of the single cropped area (SCA) and revealed that the SCA decreased. The SCA was about 2,607,000, 2,237,000, 2,133,000, and 2,110,000 hectares respectively in 2010, 2011, 2019, and 2020. This study presented a linear projection of the potential decline in the area under SCA based on the area in 2010. The results indicated a projected decrease of -32.4%, -40.4%, and -27.9% in 2028, 2029, and 2030 respectively. The double cropped area (DCA) was about 3,980,000, 4,107,000, 4,073,000, and 4,125,000 hectares in 2010, 2011, 2019, and 2020, respectively. It forecasts by 2010, there will be an expected increase of 18%, 22%, and 17% in the DCA by 2018, 2029, and 2030, respectively (Fig. 1).

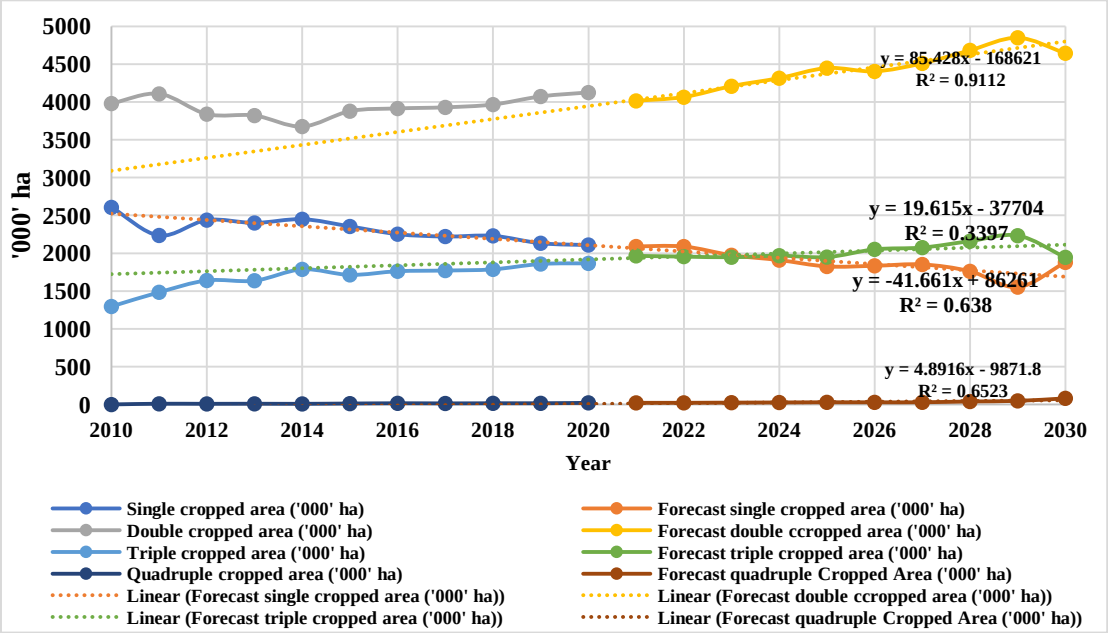

Fig. 1. Trend and prediction of SCA, DCA, TCA and QCA

The triple cropped area (TCA) was about 1,297,000, 1,485,000, 1,859,000, and 1,867,000 hectares in 2010, 2011, 2019, and 2020, respectively. The TCA was projected to experience significant growth by 2010 in the coming years, with linear forecast indicating a 67% increase in 2018, followed by further increases of 72% and 50% in 2029, and 2030, respectively. This study examined the trends in the quadruple cropped area (QCA) over the years 2018, 2019, and 2020, revealed that the QCA was approximately 17,000, 17,000, and 23,000 hectares, respectively. It was expected by 2011, the QCA will increase of 308%, 390%, and 770% in 2028, 2029, and 2030 respectively (Fig. 1).

The analysis of the four cropped areas revealed that while the SCA was experiencing a decline, the remaining three types were exhibiting an upward trend over time. One factor for this trend is that farmers might be interested in changing traditional farming patterns toward exploring alternative methods. Now the availability of quality seed, irrigation facilities, latest production technologies, regular extension support facilities, etc. are helping peasants to motivate in adopting modern farming practices. A massive increase in irrigation coverage from 7 million hectares in 2010 to 8 million hectares in 2020 indicates an overall increase of 17% of irrigated area increased multiple cropping [16]. Rahman and Mahbub [17] studied in the Barind region, and revealed the irrigation schemes motivated farmers to grow over two crops in a particular land yearly. Bhuiyan and Maharjan [18] found farmer's behavior towards farming has changed to high-value crops. Parvin et al. [19] highlighted the practice of crop diversification among farmers as a risk management strategy against the adverse effects of severe weather during harvest season and price fluctuations. Planting materials such as seed, farm machinery, compost, etc. continued to play a significant role in expanding multiple cropped area [20].

3.2 Cereals and Vegetables Cropped Area Scenario

Rice, wheat, barley, maize, and other grains are widely classified as cereals in Bangladesh. The cereals are commonly cultivated, consumed, and reflect their importance in the local agriculture and dietary systems. The present study concerned the cereals cropped area (CCA) and experienced a slight increase over the years, with values of 11,886,000, 12,073,000, 12,292,000, and 12,222,000 hectares recorded for 2010, 2011, 2019, and 2020, respectively. The linear forecast showed by 2010, there will be a 5%, 4.7% and 5.1% increase in 2028, 2029, and 2030, respectively (Fig. 2). Nasim et al. [21] found about 0.65 million hectares of fallow land are potentially suitable for additional crops, mostly cereals. Shapla et al. [22] revealed the use of hybrid seeds resulted in a notable increase of over 7% in the paddy area within the haor basin. Consequently, the food grains

production has increased by 38% as 46 million metric tons in 2021 from 33 million metric tons in 2009 [2]. This noteworthy increase in food grain production indicates the agricultural sector's growth and development, which is a crucial component of any nation's economy. The findings of this study have significant implications for policymakers and stakeholders in the agricultural sector, as they provide valuable insights into the current state of food grain production and its potential for further growth and development.

This study examined the trends in the vegetables cropped area (VCA) over the course of a decade since 2010. The VCA is a crucial indicator of the agricultural landscape, as it reflects the extent of farmland devoted to the cultivation of vegetables. Results indicated the VCA has exhibited an overall increasing trend over the study period, with values of 848,000, 883,000, 954,000, and 964,000 hectares recorded in 2010, 2011, 2019, and 2020, respectively. As per the linear projection, it has estimated that there will be a surge of 26%, 28%, and 30% in 2028, 2029, and 2030, respectively (Fig. 2).

However, the VCA increased over times, because of short-lived, fast-growing tenders [23,3]. About 90 types of vegetables grown in only 2.55% of the total cultivable area of the country. Through intensive vegetable cultivation, around 30 million metric tons of vegetables produced in 2021, when it was only 8 million metric tons in 2009 [24]. Along with commercial vegetables production, homestead and rooftop constitute a noteworthy contribution towards the expansion of the concept of Vertical Farming. Safayet et al. [25] found approximately 78% of landlords expressed a willingness to engage in the practice of rooftop farming. The rooftop gardens produce about 25 different vegetables, which are crucial for increasing VCA [26]. These findings suggested that vegetable production has been an important and growing sector of agriculture in Bangladesh. Further research is needed to explore the underlying factors driving this trend and to assess its implications for food security, environmental sustainability, and economic development.

3.3 Net Cropped Area and Gross Cropped Area Scenario

In 2010, the net cropped area (NCA) recorded about 7,885,000 hectares, while the gross cropped area (GCA) estimated about 14,459,000 hectares. Under the data from 2010, it has observed that the NCA had undergone an upward trend, with increments of 1.5%, 2.5%, and 3% in 2018, 2019, and 2020, respectively. Similarly, the GCA demonstrated an increase of 8%, 10%, and 11% in 2018, 2019, and 2020, respectively. Based on the linear forecasting model, it has projected that the NCA will experience a gradual increase of 5%, 5%, and 6% in 2028, 2029, and 2030, respectively. The GCA will anticipate experiencing a steady rise of 16%, 17%, and 18% in 2028, 2029, and 2030, respectively (Fig. 3).

Upon conducting a thorough analysis of the trends pertaining to the NCA and GCA, it has become clear that both variables had exhibited an upward trajectory over time. It means there is an inclusion of supplementary parcels of land into the NCA, which consequently results in an augmentation of the GCA. Land accreditation from watery areas, floating farming, rooftop gardening, utilizing hills for farming, etc. are

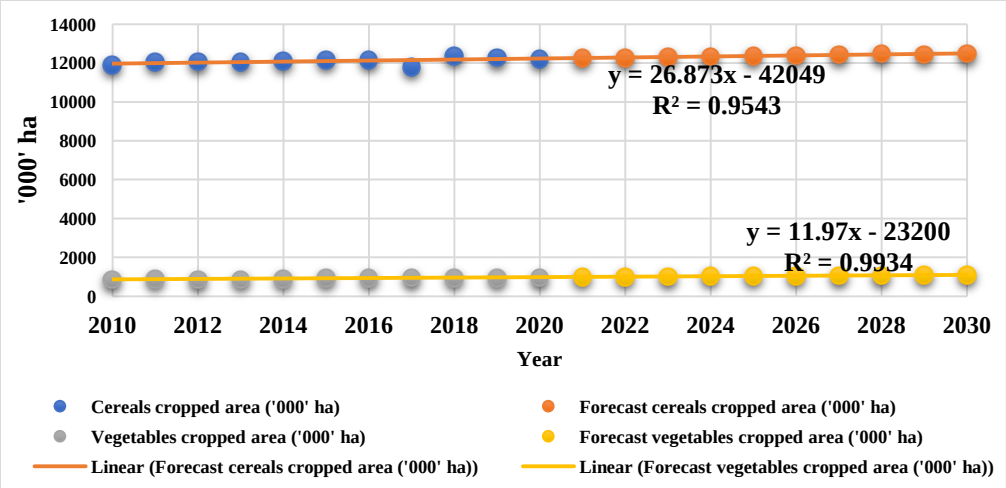

Fig. 2. Trend and prediction of CCA and VCA

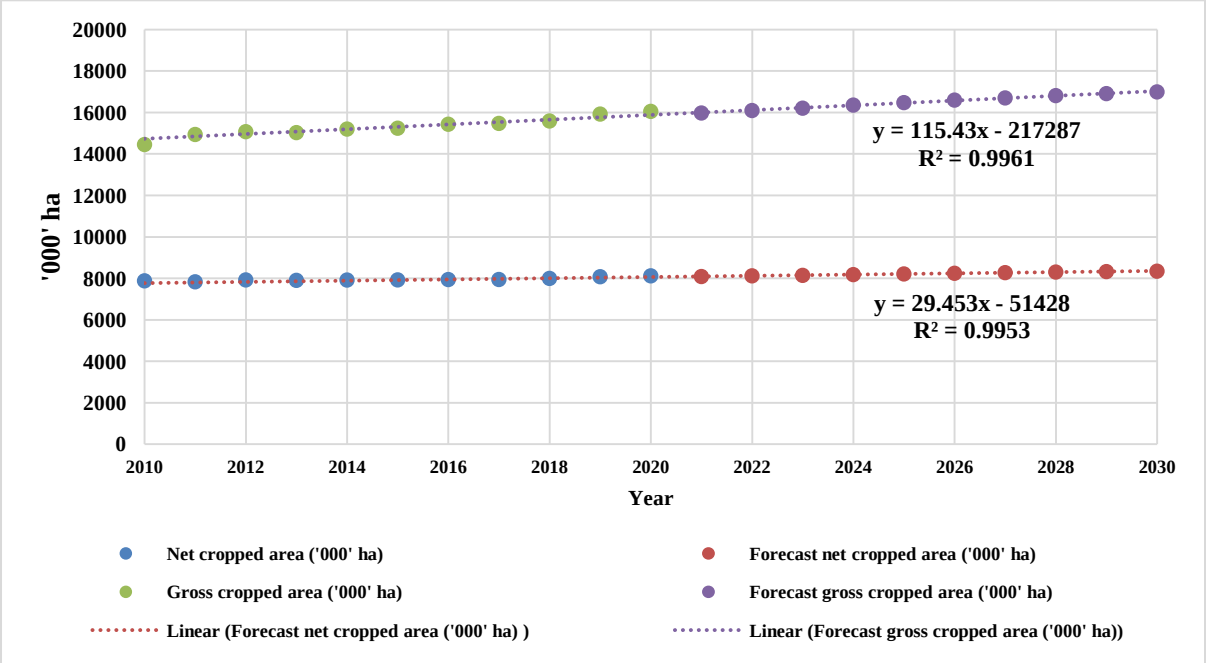

Fig. 3. Trend and prediction of NCA and GCA

might be few reasons for this trend. In the 20th century, the most remarkable achievement in vertical agricultural land transformation is the incorporation of additional lands to current cropping systems [27].

Rahman [28] estimated the extent of land accretion in coastal areas of Bangladesh increased by 4% over 58 years, from 1948 to 2006 the cropped area experienced a growth rate of 0.28% per annum between 1980 and 2000. Another study by Hasan et al. [29] revealed that during the 1970s and 2000s, over 45,520 hectares of land had accreted from the Jamuna, Ganges, and Padma rivers, while over 90,512 hectares of land had accreted in the southern coastal region. Over 5,449,792 hectares of land had added to the total land area result of fallow, river, urban and other land by 2020 [30]. According to Mainuddin et al. [31], there exists a potential to expand NCA through the utilization of approximately 0.32 million hectares of fallow land in the coastal zone during the dry season. Paul et al. [32] revealed about 5% of the Hariteka river basin in the Jessore district underwent a transformation into farm land. Islam and Ahmed [3] found that a substantial proportion of wetlands, approximately 11%, will undergo a transformation into built-up areas by 2050 in Bangladesh. Out of the haor basin's overall land size of 1.99 million hectares, MOWR [33] found that there were 1.31 million hectares of net cultivable land while developing a master plan for the area.

3.4 Cropping intensity scenario

The concept of cropping intensity (CI) is a fundamental measure of agricultural productivity that provides a comprehensive overview of the annual yield potential of a region. This metric is derived from the ratio of the total cropped area to the net sown area, and expressed in percentage. The present study revealed the CI increased gradually over the years, with values of 183%, 191%, 197%, and 198% in 2010, 2011, 2019, and 2020, respectively. These findings suggested a positive trend in the CI that offers valuable insights into the potential for increasing food production in Bangladesh. Furthermore, a linear projection by 2010, the CI will have risen by 13%, 13%, and 14% in 2028, 2029, and 2030, respectively. The increase in the CI has contributed to national food security [34]. Parvin et al. [19] and Salam et al. [35] found increasing CI is one of the quickest horizontal elements for agricultural land transformation.

The augmentation of the CI can be attributed to multitude factors, including availability of agricultural inputs, quality seed, accessibility of irrigation facilities, convenience of production technologies, and proficiency of extension support facilities. Rahman and Barmon [36] found CI of rice has increased by 13% for only using modern varieties from 1991 to 2017 in Bangladesh. Islam and Hossain [37] and Rahman and Zhang [36] found the farmers

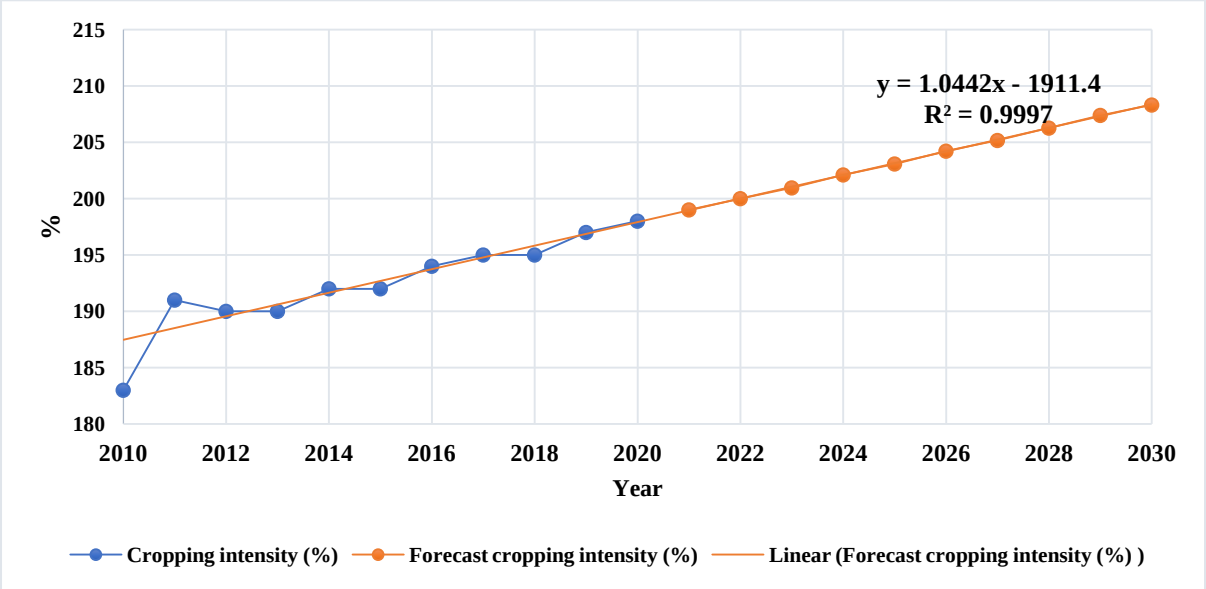

Fig. 4. Trend and prediction of CI

aware of using fertilizers and pesticides in their fields to increase agricultural production and the CI. As a result, the total consumption of chemical fertilizers per hectare has increased to 279 kg in 2014, while it was only 15 kg in 1970 [38,39]. Islam et al. [40] found the Contour Planting Model is effective to increase crop yield in hilly terrain. Rahman [28] found the CI increased by 4% at the period of 1948 to 2006. Over the past two decades, the CI has increased by producing horticultural crops, particularly fruits and vegetables [3].

4. CONCLUSIONS AND RECOMMENDATIONS

This study conducted a foresight exercise on the trend of cropped area in Bangladesh through statistical analysis. The multiple cropped area was found to be increasing, while mono cropping was declining. The cultivation of each specific farmland is necessary for agricultural diversification. Both cereals and vegetables cropped area are expanding, but the rate of expansion is comparatively higher in vegetable case. Land transformations in the Barind, watery, and saline zones contribute to accrediting new farm land, resulting in an increase in both net and gross cropped area. Utilization of accredited farm land has the potential to address the challenges effectively by the constant evolving dietary trends. As a populous country, Bangladesh needs maximum cropping intensity, because a higher cropping intensity can lead to increased food production. Overall, the gross cropped area and cropping intensity will be increased in time as the forecast results.

In the current era, one of the prime challenges is how to grow more food with a higher nutritional quality than ever before. The phenomenon of nutrient depletion in continuous cropping has been observed to have a deleterious effect on the fertility of soil. Despite increased cropped area, soil fertility loss is a major confrontation with the continued expansion and development of agriculture in some of these areas. There should be mobilized microbial activities in soil for nutrient restoration. In that circumstance, crop rotating, bio-composting, and green manuring could perform to preserve and enhance soil health. Additional investments and conduct research on shorter life-cycle varieties that possess suitable features, as well as the latest technologies with appropriate expansion are required to boost up cropping intensity.

This is a matter of great importance, as the efficient utilization of agricultural land is crucial for the sustainability of our food systems and the overall health of our economy. The government of Bangladesh should take swift and decisive action to ensure the optimal use of agricultural resources through implementing its existing policies. However, the present study does not delve into the realm of policy-related variables. The present study has yielded significant findings that could be utilized with supplementary variables and policies to simulate alterations in cropped land usage in Bangladesh. The findings

would enable the generation of more substantial recommendations that could inform decision-making processes in the future.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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