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論　文　の　要　旨

In the coastal areas of Bangladesh, agricultural land has been severely damaged by flood disasters in recent years and caused damages to farmland by cyclones. Among the South Asian countries, the most affected coastal region is the Bangladesh delta, encompasses an area of 47,201 km^2 that provides shelter and livelihood to 46 million inhabitants, with approximately 2.85 million hectares of agricultural land. Coastal areas are very much risk prone against extreme climatic events. Bangladesh Delta is reported one of the highest cyclone landfalls, which causes the changes of agricultural land use changes in shoreline areas. Due to cyclones, the damages are observed in the coastal areas of rice crops from agricultural land. In the coastal areas, damaged assessments are required in the macro to micro-scale to support the farmers after the cyclones. Therefore, the purposes of this research were to assess agricultural land use change and crop damage detection in the coastal regions from macro to micro scales using machine learning and satellite remote sensing datasets.

In this thesis, first and second chapter, the author addressed extreme climatic events occurring in the coastal regions of the global south and southeast Asian countries focusing to the disaster-prone areas. Cyclone hazards has been increased due to climate changes and causes damages in the south and southeast coastal regions of the world. The extreme climatic events cyclones frequency was the highest and the damages to agricultural lands including crop yield losses are reported significantly in Bangladesh. In the entire coastal areas of Bangladesh, out of the different extreme climatic events, tropical cyclones (42%) were recurrent to cause damaged areas, and found the highest frequency occurred in the last 45 years.

In the third chapter, the author performed shoreline change measurement in the total coastal areas of Bangladesh delta and agricultural land use change was assessed using tasseled cap transformation (TCT) from the Landsat 5 (1991), Landsat 7 ETM+ (ETM: Extended Thematic Mapper, 2006), and Landsat 8 OLI (OLI: Operational Land Imagery, 2021). The agricultural land use was the highest class among the major land use and land cover (LULC) classes. It was found 34.03%, 34.47%, and 33.52% were occupied by cultivated agricultural land use in 1991, 2006, and 2021 respectively. A total of 10% landfall of tropical cyclones occurred on agricultural land from 1977 to 1991 and from 1992 to 2006 no direct landfall over the agricultural land. Therefore, among all LULC patterns, agricultural land increased in 2006 from the year 1991. On the other hand, cultivated agricultural land decreased in the year 2021 from 2006, because 15.85% of cyclone landfall was recorded from 2007 to 2021. The significant agricultural land use changes were observed due to accelerating erosion processes from the extreme climatic events in the coastal areas of Bangladesh.

In the fourth chapter, the author performed a machine learning system to assess agricultural crop damage change detection from the cyclone Bulbul landfall on 9th November 2019, and evaluated changes based on cyclone Sitrang landfall on 24th October 2022. Among the onshore coastal areas, the most frequent cyclones affected Patuakhali district was taken to assess the damages specifically to the rice crops of agricultural lands. The results reported rice crop damage based on the changed detection (CD) classes: moderately changed detected (26.07%), very changed detected (48.83%), and extremely changed detected (17.73%) accordingly. The rice crop change detection was observed using rice growth vegetation index (RGVI)-CD with cyclone wind speed (km/h), digital elevation model (DEM), distance from the rivers, and shorelines. Cyclone Sitrang was used for the test results that were trained by Cyclone Bulbul's RGVI-CD using machine learning methods with a good-fitted test outcome ($R^2 = 0.756$).

In the fifth chapter, the author conducted the damaged area assessment of cultivated agricultural land affected by cyclone Bulbul at the micro-scale of Kalapara sub-district from Patuakhali district in the coastal area of Bangladesh. A new damaged area assessment (DAA) method was developed to measure the area of each damage type class (DTC) for cyclone-prone agricultural land. The weighted overlay method was incorporated to compute five change type classes (CTC) using the natural breaks (Jenks) method. The assessment of the damaged area classes in the croplands was reported as Not damaged (2.5%), slightly damaged (10.66%), moderately damaged (5.56%), very damaged (42.56%), and extremely damaged (18.72%).

In the sixth chapter, the author developed a fuzzy approach for satellite-derived normalized difference vegetation index (NDVI) to classify rice yield losses on a micro-scale as marginal (1.5%), slightly (8.6%), moderately (38.2%), very (18.8%), and extremely (32.9%) yield loss areas. Field validation was done based on interviews from 420 cyclone-affected registered farmers randomly. It was found that 29.5% of the reference yield information points were belonged to the moderate yield loss class and 45.2% to the extreme yield loss class individually. These field validation from registered farmers indicate that the method can be used to estimate yield losses in South and Southeast Asian countries where cyclone landfall is frequent.

In conclusion from the above discussion, the author concluded the developed methodology for damaged assessments by recurrent cyclones can be used in the coastal land use and land cover management perspectives, the damaged area assessments, classification of damaged agricultural land, classification of crop change detection and predicted rice crop yield loss area to support farmers at the coastal regions. Moreover, an emergency response management was proposed from the developed damage area classification for rice-growing farmers in the cyclone-prone areas of coastal regions in south and southeast Asia.

審　査　の　要　旨

The reduction of upland cropland due to extreme climate change, such as cyclones/typhoons, storm surges, saltwater intrusion, storm surge flooding, and backwater impacts, is a global problem today. The author's research is commendable for confronting these global challenges of extreme climatic events. The method developed by the author is referred to identify the damaged area based on cyclone wind speeds using a machine learning-based fuzzy method has not been studied in a similar way, and its novelty and usefulness are highly evaluated because the developed new method can be applied to a wide range of damaged areas in a short period of time. The novelty and usefulness of the new fuzzy-based land classification method and its application to crop yield loss prediction due to cyclones are also highly evaluated. Furthermore, new rice yield loss estimation method and proposed classification of losses are reported with field validation practically for immediate response to support farmers in the frequently affected cyclone-prone regions. Based on the above discussion, the evaluation committee judged that the academic value of this dissertation is high and appropriate as a doctoral dissertation.

The final examination committee conducted a meeting as a final examination on **July 20, 2023**. The applicant provided an overview of dissertation, addressed questions and comments raised during Q&A session. All of the committee members reached a final decision that the applicant has passed the final examination.

Therefore, the final examination committee approved that the applicant is qualified to be awarded the degree of Doctor of Philosophy in Bioresource Engineering.