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Mapping of Subsurface Waterlogged Areas in Krishna Central Delta Using ArcGIS

P Indraja, H V Hema Kumar, A Mani and L Edukondalu

College of Agricultural Engineering, Bapatla.

ABSTRACT

About 15% of the world population is affected by land degradation which is likely to worsen unless adequate and immediate measures are taken to arrest the degradation processes. Mostly land is affected by wind and water erosion, which is about 80% of land degradation followed by salinization/alkalization and waterlogging. To cope up with the growing population, the green revolution technologies overexploit the natural resources. As if these were not enough, a question mark is put on the sustainability of irrigated agriculture as the problems of water-logging and soil salinization appeared in canal irrigated command areas. One of the major paddy producing land in Andhra Pradesh, Krishna Central Delta is chosen as study area. Using collected water table observation wells data established by state Ground Water Department and ArcGIS software, the subsurface waterlogged areas were mapped from 2009 to 2016. The methodology used for the above work and the extent of waterlogging found in different years are quantified and presented in this paper. This type of study on regional basis would be an eye-opener for the policy makers and line departments to specially focus and address the subsurface waterlogging with an intent to improve the agricultural productivity in these inherently fertile lands.

Keywords: *ArcGIS, Kriging, Waterlogging, water table depth.*

Land, a non-renewable resource, is central to all primary production system. However, the growing human population and the increase in food requirements compel us to look for more land resources. Mostly land is affected by wind and water erosion, which is about 80% of land degradation followed by salinization/ alkalization and waterlogging. As if these were not enough, a question mark is put on the sustainability of irrigated agriculture as the problems of water-logging and soil salinization appeared in canal irrigated command areas. Statistics about the extent of world salt-affected areas vary according to authors; however, general estimates are close to 1 billion hectares, which represent about 7% of the earth's continental extent. In addition to these naturally salt-affected areas, about 77 Mha have been salinized as a consequence of human activities (secondary salinization), with 58% in irrigated areas. In India, the National Commission for Irrigation (1972), National Commission on Agriculture (1976), and the Ministry of water resources (1991) have estimated the extent of waterlogged area as 4.84, 6.00 and 2.46 m ha, respectively. In Andhra Pradesh alone, the estimated area under waterlogging is 2.66 lakh hectares under irrigated commands (Ministry of water resources (MoWR-1991).

Choubey (1998) attempted to make an assessment of waterlogging in Sriram Sagar command area, India by using remotely sensed data and validated with water table data and other field information. The results obtained from this study indicated that in April and October 1989, areas of 388 and 540 km^2 were waterlogged and about 698 and 802 km^2 respectively, were sensitive to waterlogging. Chowdary *et al.* (2008) assessed surface and sub-surface waterlogged areas in irrigation command areas of Bihar state using Remote Sensing and GIS. Pre-monsoon and post-monsoon surface waterlogged areas were delineated in all the 132 irrigation command areas of the Bihar State, India using Indian Remote Sensing (IRS-1D) Linear Imaging Self Scanning Sensor (LISS-III) data and found that 628×10^3 ha was waterlogged. By analyzing pre and post monsoon ground water levels under GIS environments the sub surface waterlogged areas was found.

Abhay (2014) conducted a study on Moyna Basin to identify and map the waterlogged areas (India) using Remote Sensing and GIS methods. The Landsat 5 TM, ASTER data, and topographical sheets were considered with field observations. It was observed that total area under waterlogging in the Monya basin is around 59 sq.km. Getahun *et al.* (2015) conducted severity classification and characterization of waterlogged irrigation fields in the Fincha, a valley sugar estate (FVSE), Nile basin of Western Ethiopia using GIS and Remote Sensing and other ancillary information. Results indicated that about 324.4 km^2 (75.5%) of the delineated plantation fields were severely waterlogged and 105 km^2 (24.5%) were critically waterlogged.

Krishna delta irrigates an ayacut of 5.14 lakh hectares covering West Godavari, Krishna, Guntur and Prakasam districts of Andhra Pradesh. Eastern main canal's command area is about 2.948 lakh ha in Krishna and West Godavari Districts. The Krishna Eastern Main Canal Command Area is divided into two divisions namely Krishna Central Delta(KCD) covering majority of Krishna district and Krishna Eastern Delta.During monsoon, these lands are affected by waterlogging and salinity problems. Hence this research work entitled "Mapping of subsurface waterlogged areas in Krishna Central Delta using ArcGIS" was taken to assess the extent of subsurface waterlogged lands using the ground water table observation wells data and Arc GIS.

MATERIAL AND METHODS

Before discussing the methodology followed to accomplish the objective, the preliminary description of study area details, soils, climate, cropping pattern and satellite images used for the study are discussed.

Description of Study Area

The study area selected was Krishna Central Delta, a part of Krishna Eastern Delta in Krishna district which is named after the holy river Krishna, bounded by the latitudes 16º 37' 15" and 15º 42' 15" N and longitudes 80º 34' 0" and 81º 16' 0" E. This district is located on the north-east coast of Andhra Pradesh state in India.

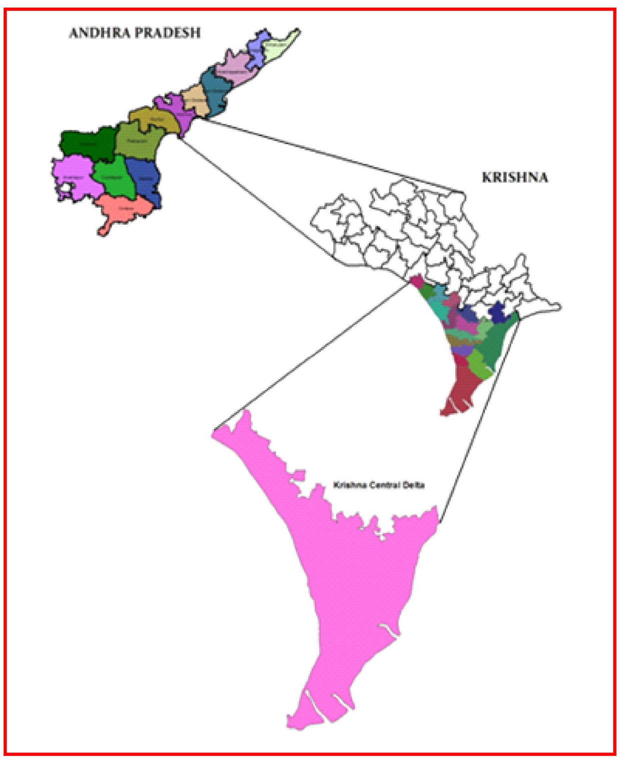

Fig. 1 Location of Krishna Central Delta

Krishna district is developed agriculturally mainly due to the irrigation canals from Prakasam Barrage constructed on the river Krishna near Vijayawada. Krishna Central Delta constituted the Bandar canal command area which has two major branch canals, Bandar direct and Krishna East Bank canal.

Climate

Tropical climate conditions with extreme hot summer and cold winter prevails in this District. April to June are the hottest months with high temperature in May. Temperature in the district begins to rise from the middle of February till May that is to an average of about 38°C. KCD receives around 1115 mm rainfall of which about 60% occurs during the south- west monsoon from June to September.

Soils

In Krishna Central Delta (KCD) the major soil type that occurs in almost all mandals is calcareous soil that has highest percentage of calcium carbonate, it accounts for about 67.86% (i.e., 1478.16 km^2) of total area. Then the second major soil type is clay soil, it accounts for about 19.01% and covers about 414.19 km^2.

Irrigation Practices and Agricultural Crops

The amount and timing of water releases from the Prakasam barrage in Vijayawada is being determined by the Water Resources Department. When sufficient water is available, continuous flows are set in. In the study area during the kharif season (July/August-November/December) the major crops grown are paddy and sugarcane and during the rabi season (December-March) the predominant crops grown are paddy, groundnut, maize and some extent with pulses. Sugarcane is also grown as major crop in the north-eastern part of the study area.

ArcGIS

ArcGIS is a software program, developed by Environmental Systems Research Institute (ESRI) of Redlands, California. ArcGIS is used for creating and using maps; compiling geographic data; analyzing mapped information; sharing and discovering geographic information in a range of applications; and managing geographic information in a database. ArcGIS for Desktop consists of several integrated applications, including ArcMap, ArcCatalog (data management application, used to browse datasets), Arc Toolbox (contains different geoprocessing, data conversion and analysis tools along with much of the functionality in Arc Info), ArcScene, ArcGlobe, and ArcGIS Pro.

Mapping of Sub Surface Waterlogged Areas

From the Ground Water Department, Vijayawada the water table data of observation wells located in the Krishna Central Delta was collected from 2009 to 2016. Monthly data was available in some mandals where piezometers were installed and from locations of observation wells bimonthly data was available. The spatial location of the observation wells in KCD was shown in Fig. 2. Averages of Pre and Post monsoon period water table depths (WTD) were calculated and attributed to the observation well data. For both pre and post monsoon seasons the Kriging interpolation technique, a spatial analyst tool was run in ArcGIS for all the years 2009-2016, to study the spatial variation of water table depths and to identify the sub surface waterlogged areas.

Further, they were reclassified into 4 classes namely, class1(most critical): WTD<1m, class 2(critical): 1<WTD <2m, class 3(less critical): 2 <WTD <3m and class 4 (not critical) : WTD >4m. (Chowdary *et al.,* 2008).

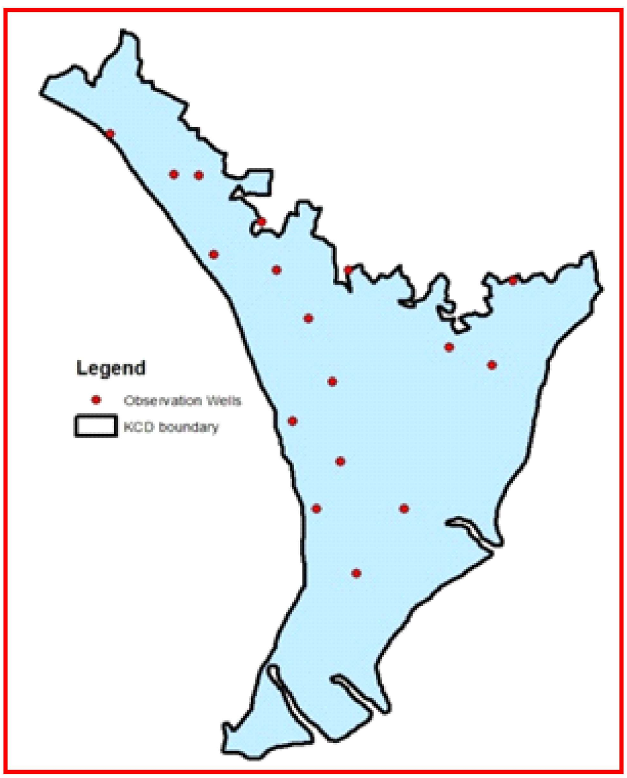

Fig. 2 Spatial location of observation wells in KCD

Kriging Interpolation Technique

The water table depth values for both the pre- and post-monsoon seasons were interpolated spatially using the Kriging interpolation technique (spatial analyst tool) available in ArcGIS. Kriging is a powerful statistical interpolation method used for diverse applications. It assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. It fits a function to a specified number of points or all points within a specified radius to determine the output value for each location. Kriging is most appropriate when a spatially correlated distance or directional bias in the data is known.

RESULTTS AND DISCUSSION

Using the water table depth (WTD) data of all the mandals in Krishna Central Delta, for each and every year Kriging interpolation option available in ArcGIS was used separately for pre and post monsoon. For better interpretation, using spatial analysis tool combining the waterlogged zones of similar classes in both pre and post monsoon yearly waterlogged maps were developed. Maps showing the different classes of waterlogged conditions in KCD from 2009-2016 was shown in Fig. 3(a) & 3(b).

Spatial analysis of water table data reveals that most critically waterlogged zone was found intense in the years 2011 and 2016 covering an extent of 14.74 and 443.19 km^2 respectively. The area under critically waterlogged zone was decreased from 1208.01 to 487.04 km^2 in the years 2010 to 2016 respectively. In all the years critically waterlogging condition prevails in KCD region covering an aerial extent of 1007.85, 1208.01, 827.91, 730.42, 613.82, 762.95, 583.32 and 487.04 km^2 from 2009-2016 respectively. In KCD, area under less critically waterlogged zone was found to range from 337.4 to 1188.39 km^2 in the years 2016 and 2013 respectively. The area under less critically waterlogged zone in the years 2009, 2010, 2011, 2012, 2014 and 2015 was 703.78, 602.23, 854.95, 1053.59, 950.92 and 936.99 km^2 respectively. In KCD the area that is safe from waterlogging was found to range from 464.99 to 1007.64 km^2 in the years 2010 and 2016 respectively. The area under classified waterlogged conditions in KCD from 2009-2016 was shown in Fig. 4.

As there is a considerably more variation in individual years, it is felt wise to consider the average water table depths of pre and post monsoons for all the years and were mapped for KCD region using the Kriging option of ArcGIS. The pre monsoon and post monsoon waterlogging maps are shown in Fig 5. Most critically waterlogged zone was found in post monsoon covering an area of 597.65 km^2 which was about 26.27% of the total study area. It was found that waterlogged area increased from 620.12 km^2 (27.25%) in pre monsoon period to 1074.02 km^2 (47.2%) in post monsoon period. The area under potentially waterlogged area was found to be decreased from 704.49 km^2 (30.95%) in pre monsoon to 163.06 km^2 (7.16%) in post monsoon period.

During pre monsoon most of the area under critically waterlogged condition has been reclassified

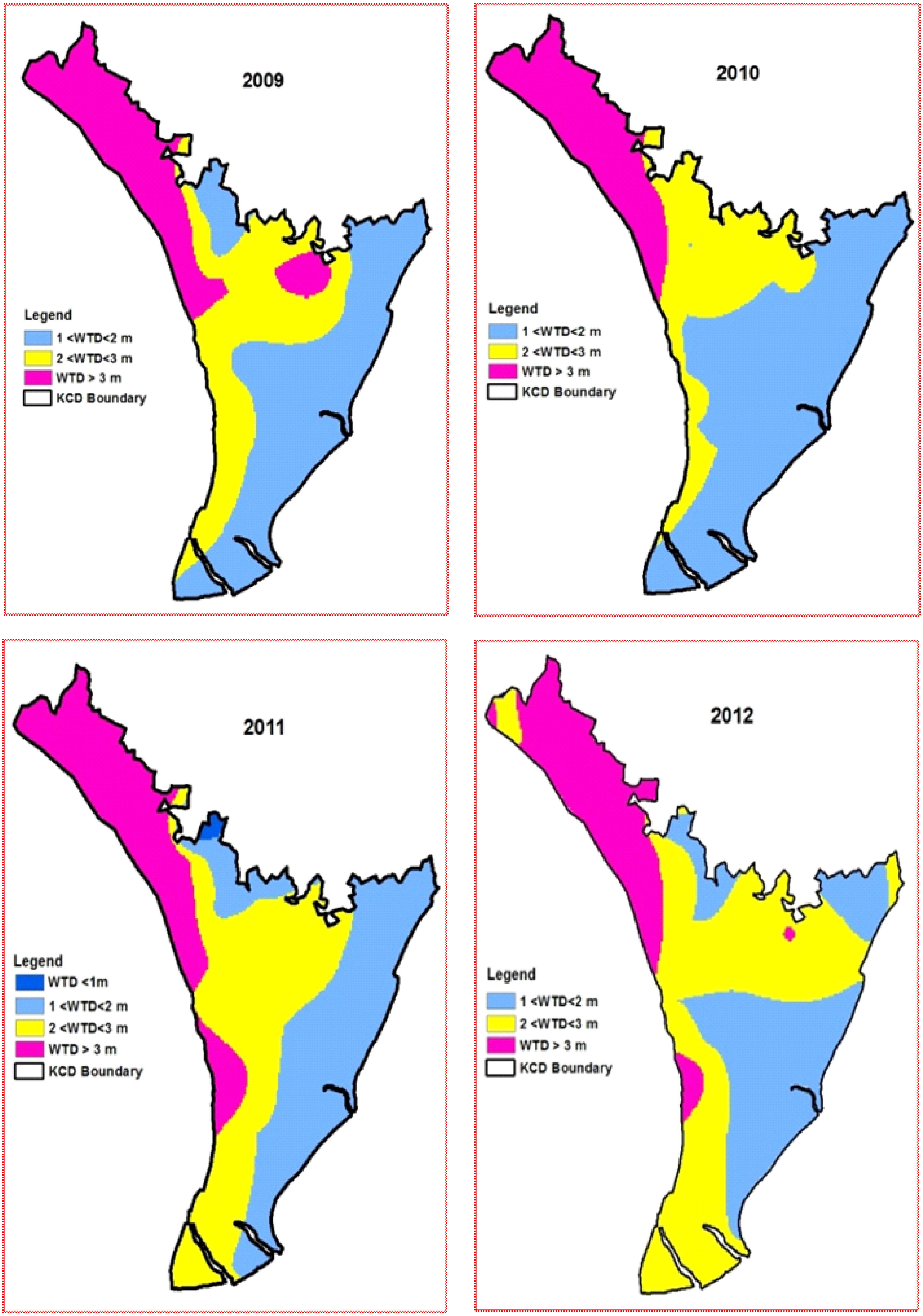

Fig. 3 (a) Sub surface waterlogging conditions in the study area from 2009-2012

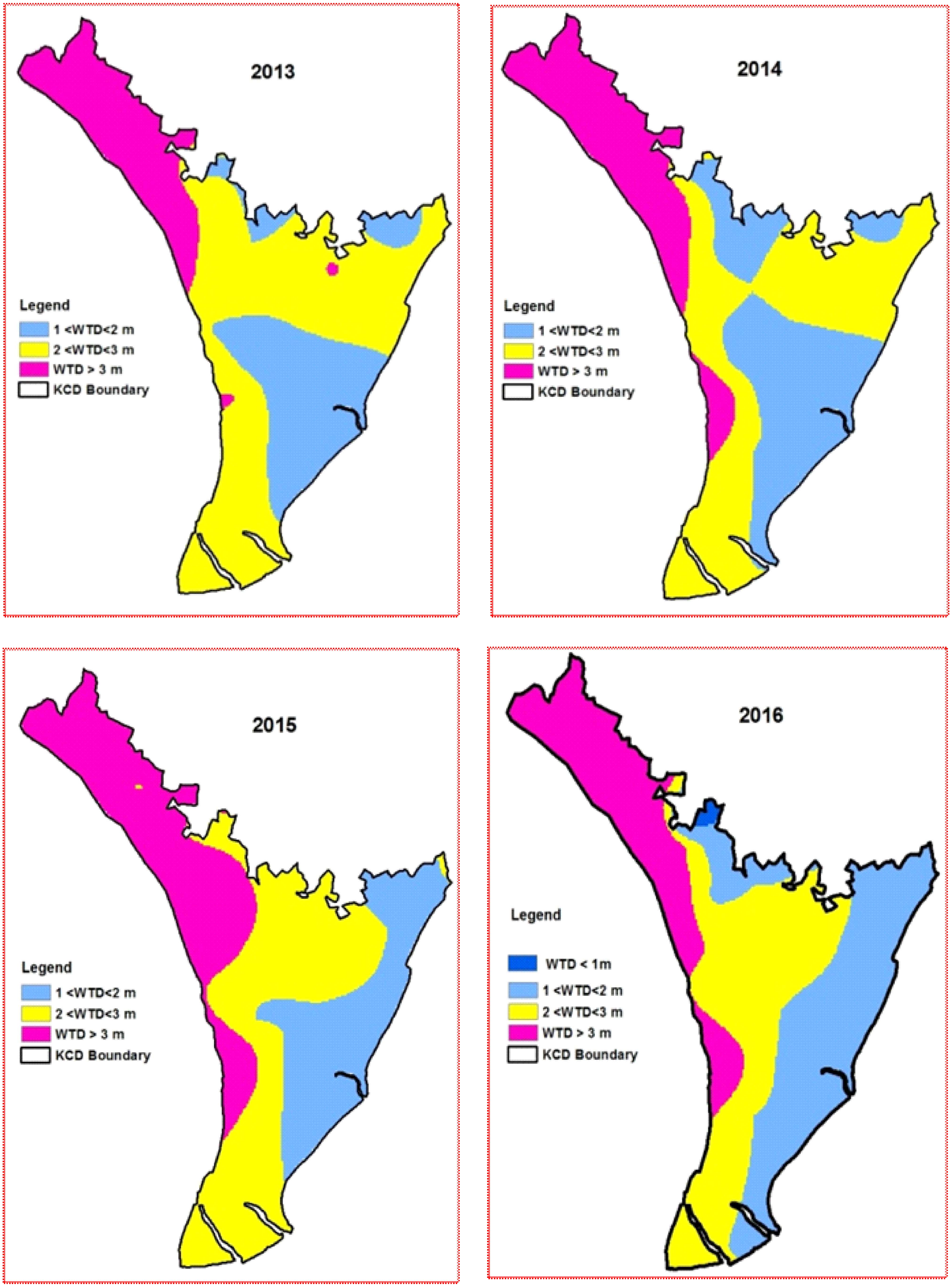

Fig. 3(b) Variation in sub surface waterlogging conditions in KCD from 2013-2016

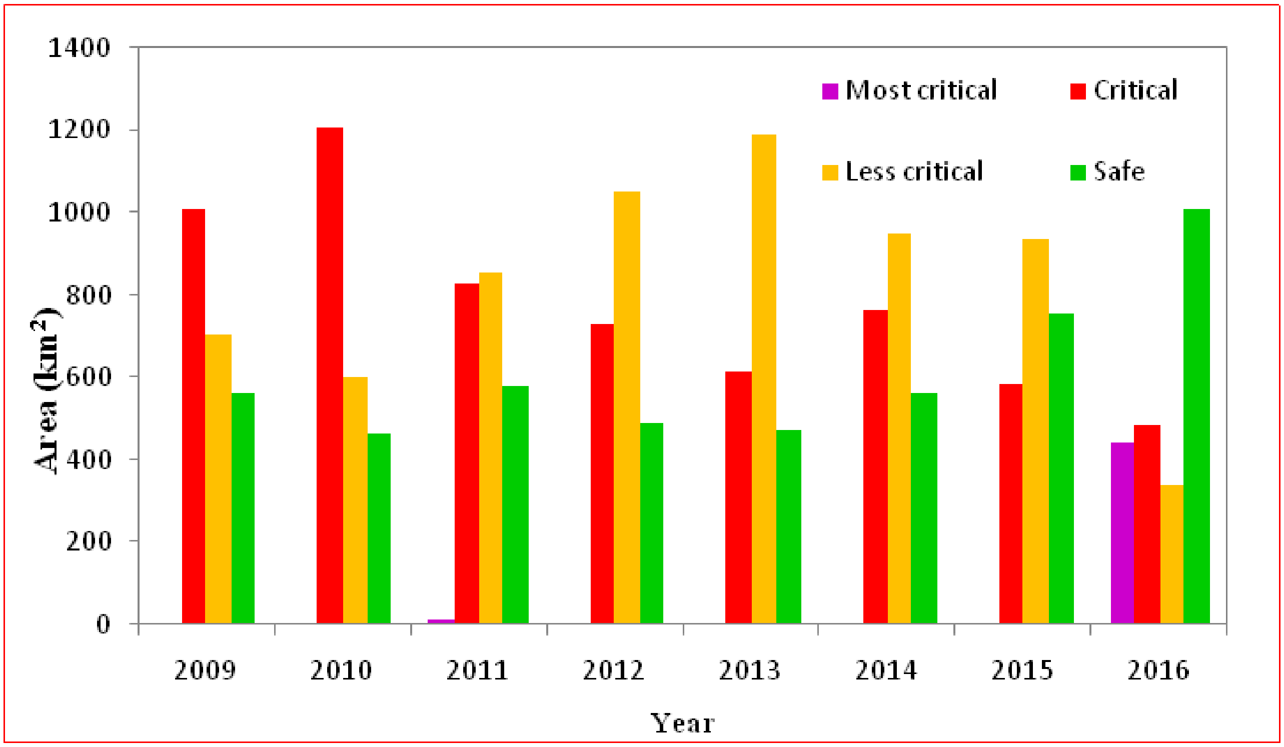

Fig. 4 Area under different waterlogging conditions in KCD from 2009-2016

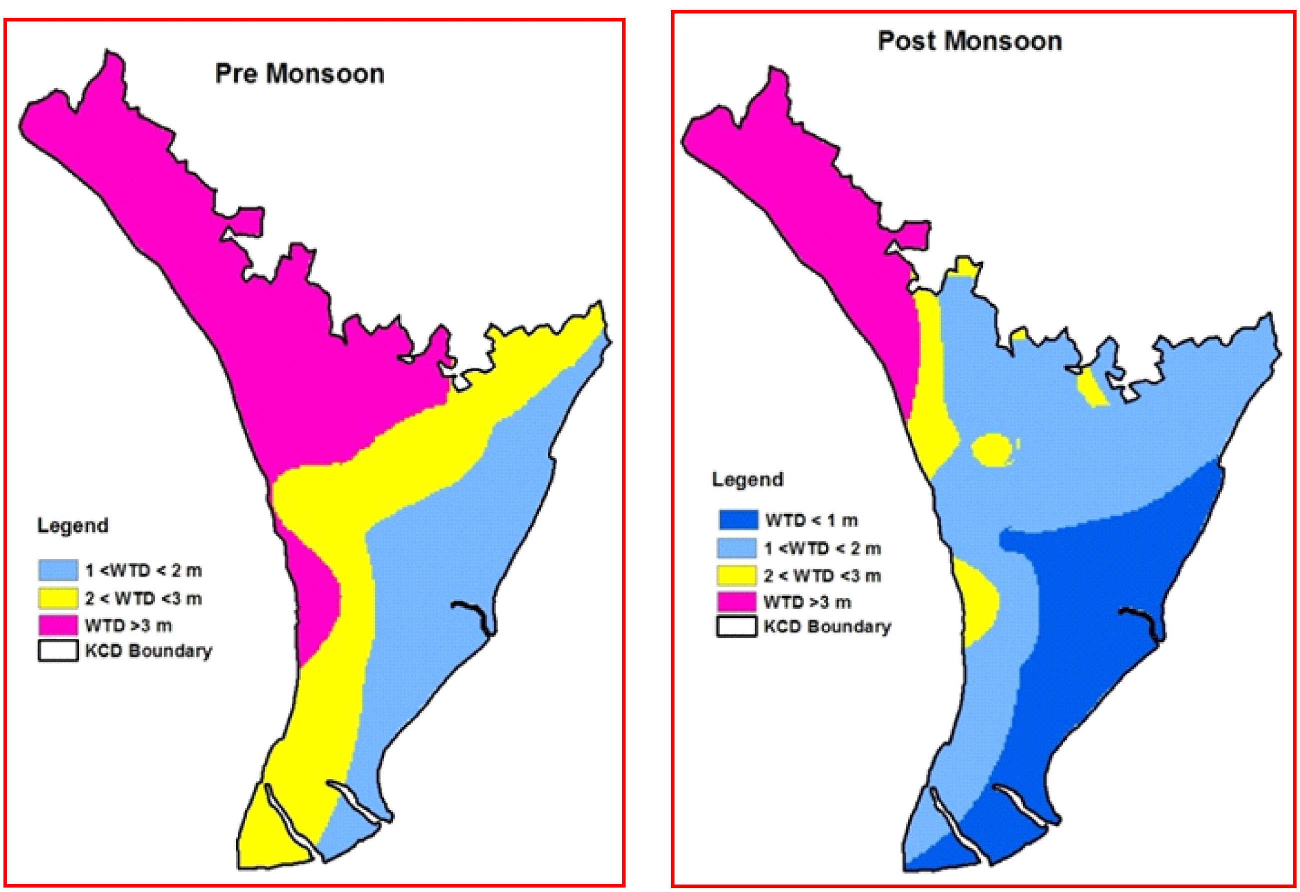

Fig. 5 Average pre and post monsoon sub surface waterlogging in KCD (2009-2016)

into most critically waterlogged area in post monsoon due to the occurrence of rainfall during post monsoon periods accordingly the rise of water table takes place and the corresponding class changed. The area under less critical waterlogged condition increased in post monsoon period when compared with pre monsoon period. Whereas the area under not critical waterlogged condition is found to be in decreasing trend from pre monsoon period to post monsoon period there by bringing much area under waterlogged or potentially waterlogged conditions. It was also found that throughout the period, the coastal mandals of study area, viz., Nagayalanka, Koduru and Machilipatnam were found to be under waterlogged conditions most of the times. In pre monsoon period as the water table depth increases the area under not critical waterlogged condition was high but with onset of monsoon the water tables rises and thereby the area under not critical waterlogged conditions has been decreased.

The variation in the aerial extent under individual class of waterlogging may be attributed to mainly the variations in canal releases, temporal distribution of rainfall and the cropping pattern followed in that particular year. However, this analysis would help in addressing the waterlogging problem location wise as per the existing drainage facilities like disposal drains nearby, elevation of the drain compared to the fields or randomized pumping etc., Hence this type of study would enable the local line departments to focus the issue as per the severity and it could be possible to recommend suitable reclamation measures.

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