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RESEARCH PAPER

Spatial association of soil salinity with topography, land use and land cover in the Aghanasini estuary

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Abstract: A study was conducted to understand the relationship between land elevation, land use/land cover and soil salinity in coastal cultivated soils of Aghanashini estuary of Uttara Kannada district, Karnataka. Soil salinity was estimated during pre-monsoon (April-May) and post-monsoon (November-December) of 2018 and 2019 by random surface sample collection and analysis. Soil salinity polygons were drawn and overlaid on topography, land use and land cover spatial data by using Arc GIS software to understand the pattern and its spatial relations. Land elevation had significantly influenced the surfacesoil salinity. The lands situated inlower elevations (0 - 25 m above MSL) had higher soil salinity (> 8dSm^{-1}) compared to lands on higher elevations (> 75 m above MSL). Among different land uses, aquaculture (prawn farming), wet land, mangrove and mud flat exhibited higher soil salinity of >8 dS m^{-1}.

Key words: Aghanashini estuary, Elevation, Land use, Land cover, Spatial association

Introduction

Soil salinity in coastal soils are highly dynamic. Soil salinity is one of the most limiting factors in land evaluation and management for agricultural use as it impacts crop production directly. Coastal saline soils are characterized by high degree of spatial variability due to combined effect of physical, chemical and biological processes that operate with different intensities and at different scales. Soil salinity has severe consequences on ecological functions of soil, water, climate and agriculture. Spatial variability of soil salinityis a function of environmental factors such as climate and landscape characteristics, topography, slope, elevation, parent materials and native vegetation (Maleki *et al*., 2013). Topography and land use/cover play a primary and important role in designing sub-surface drainage system for saline soil reclamation. Additionally, comprehensive information on the spatial distribution of land use/land cover categories and topography are pre-requisite for planning, utilization and management of the coastal resources. Therefore, for greater development and implementation of efficient saline soil reclamation programs and preventing any further salinization, capturing of information on the spatial extent, nature and distribution of soil salinity is very essential. Thus, timely detection of soil salinity, monitoring and assessment of its severity level and extent become very important at local and regional scale.

Therefore, understanding the relationship between land elevation and land use/land cover with soil salinity isessential in planning and management of coastal saline areas. An attempt was made in coastal cultivated soils of Aghanashini estuary of Uttara Kannadadistrict, Karnataka to explore the relationship between surface soil salinity and land features such as topography and land use/cover.

Material and methods

Description of the study area

The study area is Aghanashini estuary located in Kumta *taluk* of Uttara Kannada district of Karnataka (Fig. 1). The Aghanashini estuary lies between 14.5208^0 and 14.5393 ^{0}N latitude and between 74.3537^0 and 74.3690^0 E longitude. Aghanashini river originates in the Western Ghats (Manjguni) and flows westward towards the Arabian Sea. Major part of its course runs through forested gorges and valleys. The river meets the sea in the Aghanashini village of Kumta *taluk*. This river has a catchment area of 1449 km^2 and it has no dam and no notable industrial establishments or major townships along its banks.

The topography on either side of the river valley becomes more varied and irregular because of the lateritic hills and granitic terrain. The elevation ranges from 0-100 m above mean sea level (MSL). The geology of the area consists of rock formation of Archean complex consisting of Archean granites and gneisses with their sparse bands of Dharwar system of rocks. The climate of the area is characterized by high humidity nearly all the year round. The rainfall is plentiful with a mean annual rainfall of 3,538 mm. The major crops in the area are

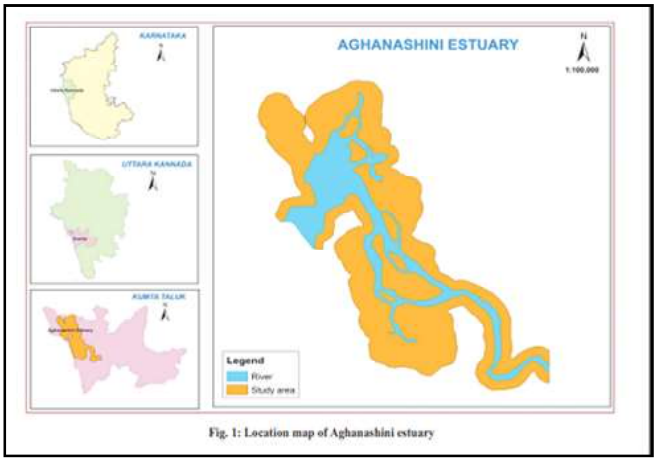

Fig. 1. Location map of Aghanashini estuary

coconut, paddy and pulses. However, due to inundation of the marine water along river course, during non-rainy season, most of the land remains fallow. The brackish water in undated land (*gajani:* local name) is used for prawn cultivation.

The digital elevation model used in this study was high resolution CARTOSAT-1 DEM Stereo data (C1_DEM_16b_2006-2008_V1_74E14N_D43I with 2.5 m resolution). High-resolution CARTOSAT-1 DEM provides higher accuracy of 0.42 RMSE than SRTM and ASTER DEM (Bothale and Pandey, 2013). The data was polygonised into contour segments at 25m interval in GIS environment and a shape file was created (Fig. 2).

Soil samples were drawn at 250 m distance from 0-20 cm depth from the estuary during pre-monsoon and post-monsoon seasons of 2018 and 2019. The entire cropped area all along and across the estuary was traversed and sampled. The samples were shade dried, pounded and 2 mm sieved and analysed for saturated paste electrical conductivity. Grid electrical conductivity values were kriged and salinity polygons were created and saved as shape file. Land use/ cover data was captured by physical traversing and also from the Kumata *taluka* office of the agricultural department. The digitized polygons maps were created in shape file format.

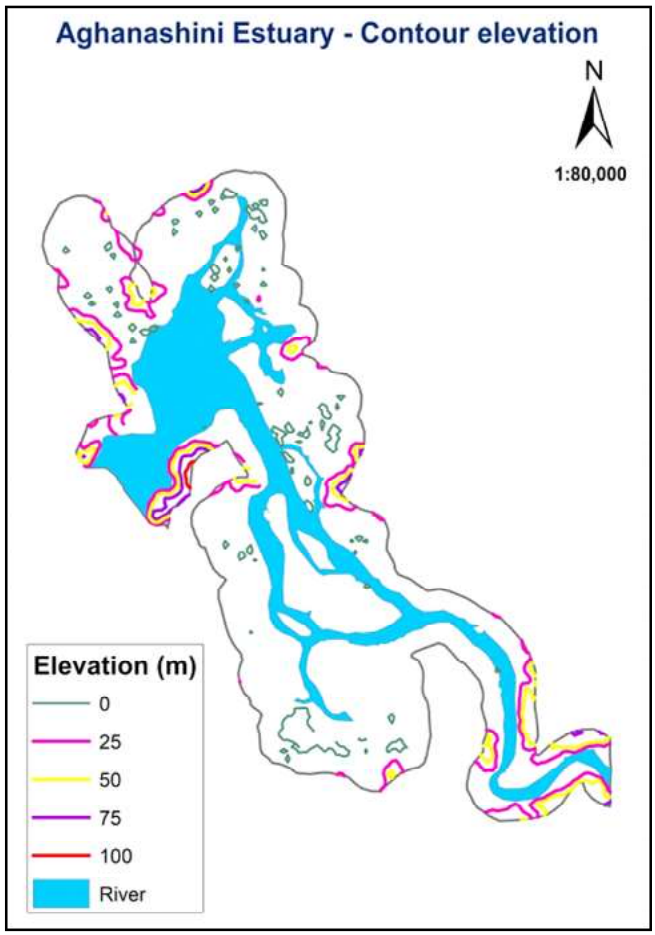

Fig. 2. Contour elevation map of Aghanashini

To understand the pattern and spatial association of surface soil salinity with topography and land use and land cover, soil salinity polygons were overlaid on contour, land use and land cover spatial data and studied for pattern and spatial relation.

Results and discussion

Relationship between contour elevation and surface soil salinity

Elevation of the land in the study area variedfrom0 to 100 m above MSL and the same is depicted in a segmental map generated (Fig. 2) at 25 m contour interval. Major portion of the study area wasunder lower elevation of 0-25 m above MSL and it was mostly closer to the river course line (Fig. 3 and 4). Overlaid map of soil salinity of pre-monsoon season 2018 and contour elevation revealed that the major portion of strongly (>16 dS m^{-1}) and moderately saline (8-16 dS m^{-1}) areas fell under contour elevation between 0 to 25 m. This area was either fallow or under prawn cultivation.

On the other hand, slightly and non-saline (0-2 dS m^{-1}) areas predominantly occurred in higher elevationof more than 75 m above MSL (1486 ha: 24% of TGA). In case of post-monsoon season 2018, major portion of moderately saline (8-16 dS m^{-1}) area (3186 ha TGA; 52% of TGA) was under contour elevation between 0-25 m above MSL. Due to underground seepage of the brackish water along the river course.The recurrent and seasonal inundation of this area makes it suitable for either *kagga*rice cultivation during monsoon season or put to prawn cultivation during post monsoon season. The lower land elevation does not permit installation of the sub-surface/ surface land drainage system;therefore,it is neither suitable for arable crop cultivation nor for plantation crops.

In case of pre-monsoon season 2019, there was an increase in strongly saline area (> 16 dSm^{-1}) compared to pre-monsoon season 2018. Major portion of strongly saline class land (3971 ha; 65 % of TGA) came under contour interval between 0 to 25 m above MSL. Similarly, in case of post-monsoon season 2019, strongly and moderately saline area fell under contour elevation between 0 to 25 m above MSL. Major portions of very slightly saline areas (658 ha; 11 % of TGA) were categorized under contour elevation between 25 to 50 m and 50 to 75 m above MSL (Fig. 4).

From the relationship between elevation and soil salinity, it could be inferredthat the major portion of strongly (>16 dS m^{-1}) and moderately saline (8-16 dS m^{-1}) areas (average area over 2018 and 2019, 5500 ha) fell under contour elevation between 0 to 25 m above MSL irrespective of season and year. However, compared to pre-monsoon season there is a decrease in area of strongly saline soils in post-monsoon season.This may be due to leaching/flushing of salts from land surface by heavy rainfall during rainy seasons. Fresh water flow in the river inundates, most of area with 0-25 m above MSL also flushes out salinity from soil surface. Contrastingly, the higher land areas lying between 25-50 m and 50-75 m were observed with slightly (4 - 8 dS m^{-1}), very slightly saline (2- 4 dS m^{-1}) and non-saline (0- 2 dS m^{-1}). Crop lands at higher elevation did not show any salinization as they were not exposed for seawater inundation.

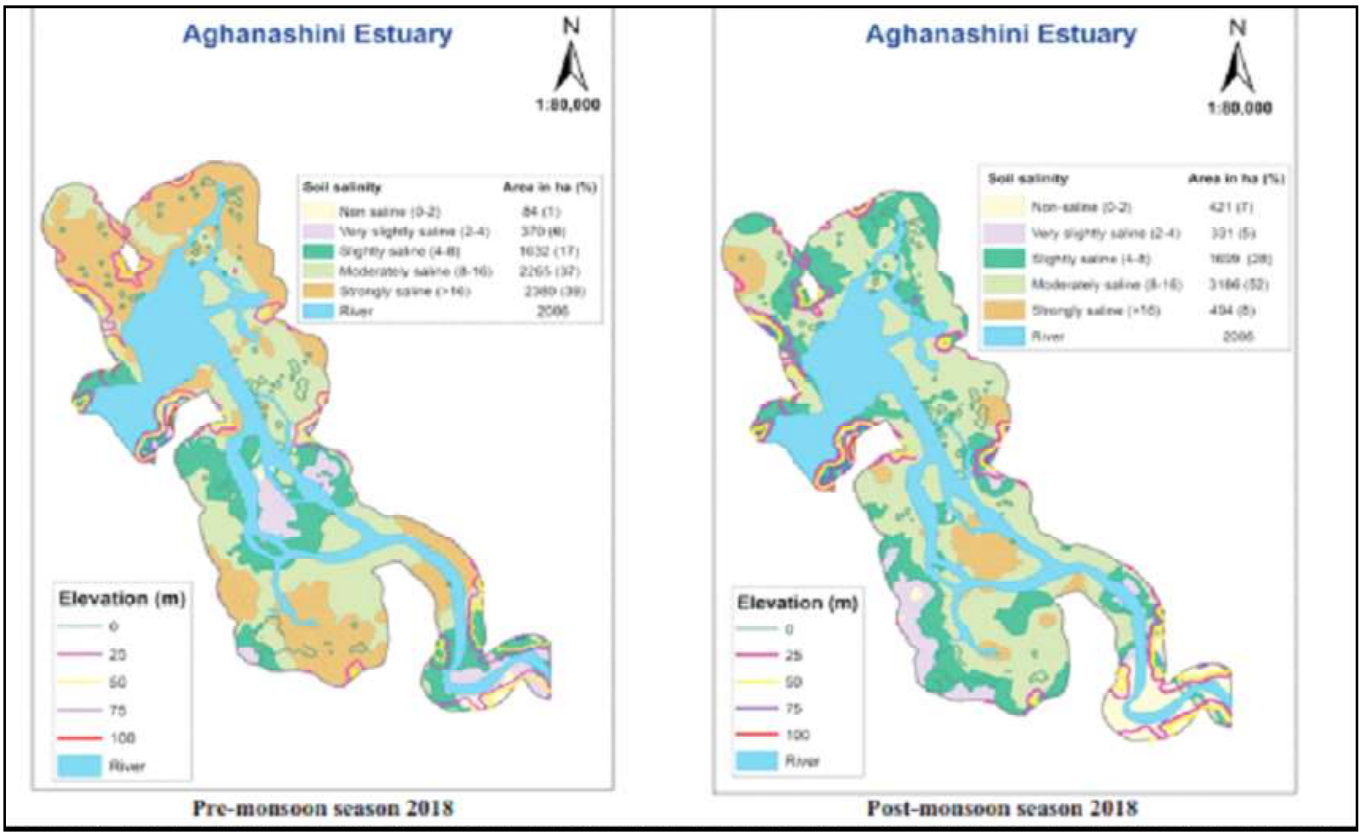

Fig. 3. Relationship between contour elevation and soil salinity of Aghanashini estuary during pre and post-monsoon season 2018

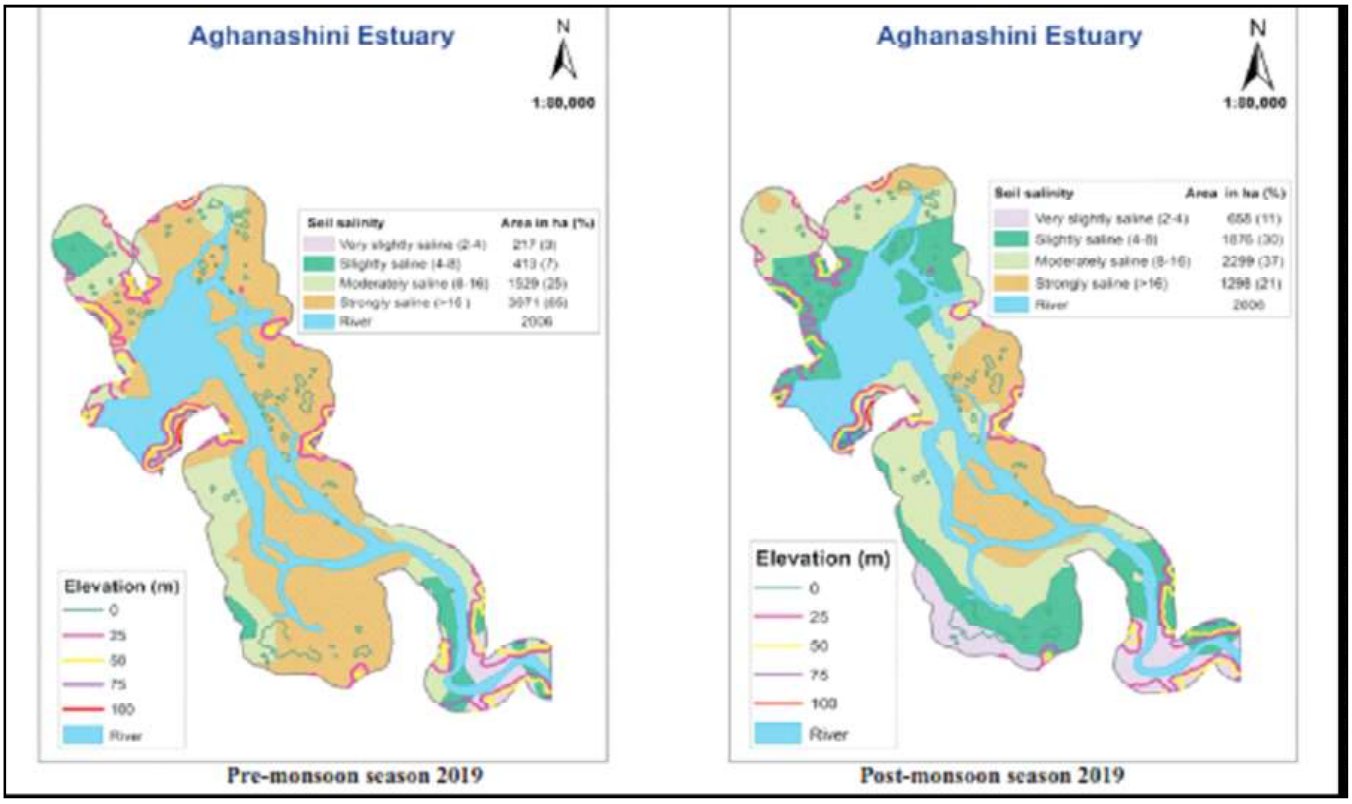

Fig. 4. Relationship between contour elevation and soil salinity of Aghanashini estuary during pre and post-monsoon season 2019

In addition, excessive leaching of salts during rainy season might have resulted in low salinity. Soils of the entire estuary area werestrongly acidic which further validates that soils are intensely leached. Qanbari and Jamali (2015) reported that at lower elevations, soil salinity is greater than the higher elevations due to the transmission of the material by runoff and their accumulation in the lower parts of the watershed.

Surface and root zone soil salinity is greatly influenced by water table facilitating capillary rise of brackish water. Lower elevated lands all along river course in the estuaries favour underground and surface seepage of saline sea water during pre-monsoon seasons. During these seasons fresh water flow in the river is reduced. Additionally, land use also plays major role in coastal land salinization. The commercial activities such as prawn cultivation in surface ponds, salt harvesting and *kagga* rice cultivation in the brackish water inundated lands (*Gajani* lands) are adding to the increased coastal soil salinity. The farmers modify land configuration by farming bunds and other water flow regulatory structures thereby natural flow/ seepage of water is adversely affected.

Relationship between land use/land cover and soil salinity

Land use/land cover map describes the spatial distribution and extents of features in a geographical area and it is an indication of ecological and overall socio-economic status. Land use/land cover provides information about present land use and forms base line information for the sustainable land use planning and further development.

Major portion of the study area was occupied by Aghanashini river with an area of about 2,006 ha (25 % of TGA). The agriculture and natural vegetation occupied an area of about 1,427 ha (17 % of TGA) and 924 ha (11 % of TGA), respectively. Aquaculture is the associated enterprise ofagriculture in the study area and mostly occurred adjacent to the river and occupied by an area of 1619 ha (20 % of TGA). Mangroves, the typical forest type occupied by an area of 184 ha (2 % of TGA) and was observed in patches between the river and main land. Plantation and habitation with vegetation occupied an area about 741 and 342 ha, respectively. A wet land, salt pan and mud flat occupied an area of 533, 154 and 36 ha, respectively in the study area. While barren land occupied an area of 172 ha (2 % of TGA),

Over laid polygon maps of soil salinity (both pre and post-monsoon season 2018 and 2019) and land use/land cover in the study area are presented in Fig. 5 and 6. Land use with aquaculture, wet land, mangrove and mud flatwere under lower elevation had associated with higher surface soil salinity (> 8 dS m^{-1}). However, slightly, very slightly and non-saline classes were either barren land or under natural vegetation. The land under aquaculture (1,619 ha; 20 % of TGA) was the most saline area in Aghanashini estuary.Cropped land (1427 ha) and vegetation (924 ha) were either non-saline (< 2 dSm^{-1}) or slightly-saline (2-4 dSm^{-1}).

In addition to the topography, the land use is also influencing soil salinization. Land use and land cover change (LUCC) has been recognized as a major driving force of global environmental perturbations. Elucidating the influence of LUCC on soil salinity is fundamental effective measures for ameliorationsoil salinity. Land use with aquaculture, wet land, mangrove and mud flat are associated withhigher soil salinity

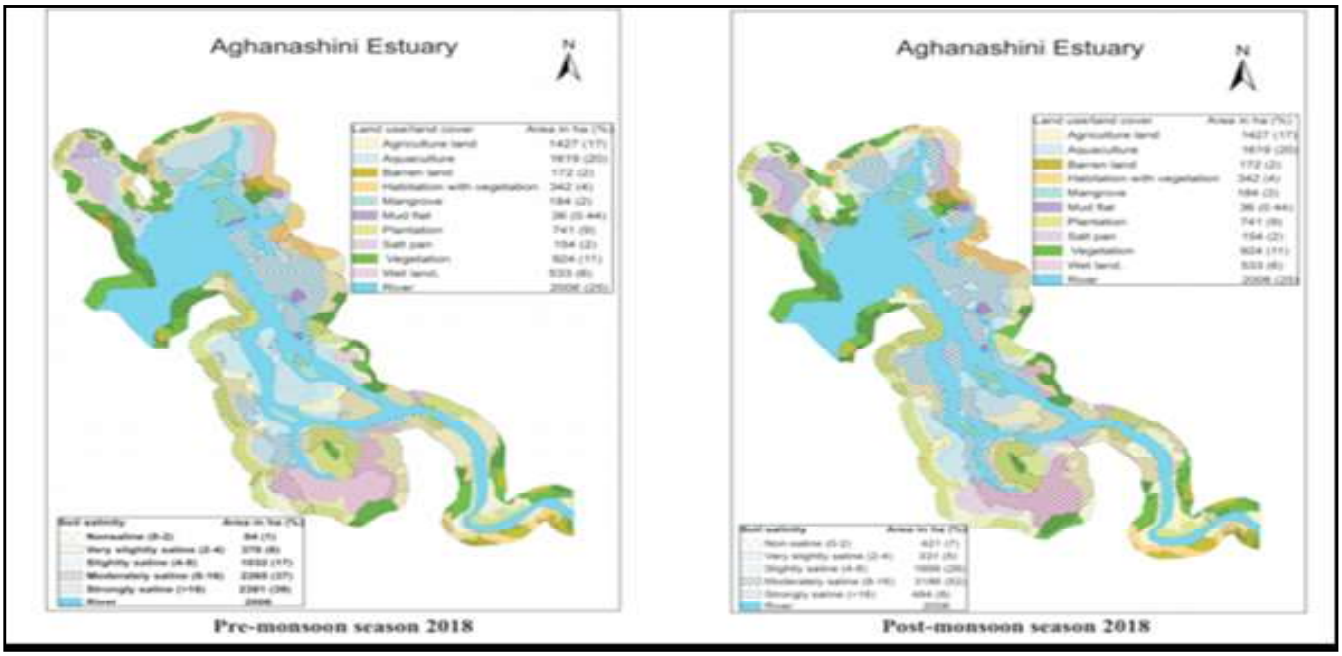

Fig. 5. Relationship between land use/land cover and soil salinity of Aghanashini estuary during pre and post-monsoon season 2018

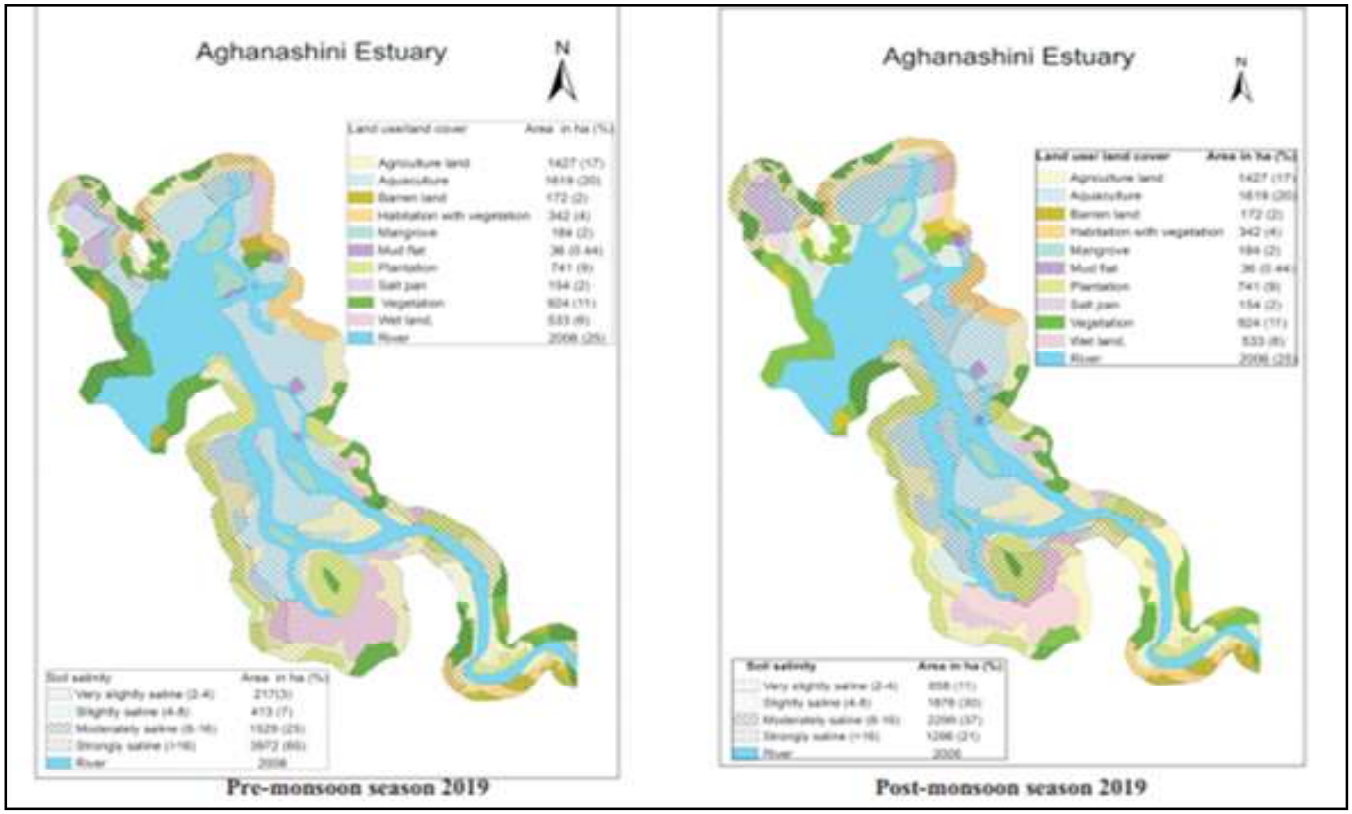

Fig. 6. Relationship between land use/land cover and soil salinity of Aghanashini estuary during pre and post-monsoon season 2019

(> 8 dS m^{-1}) due to underground seepage of brackish water and also surface ponding.

Conclusion

Soil salinity is a factor that affect plant growth and development especially in coastal region. From the relationship between elevation and soil salinity, it is inferred that major portion of strongly (>16 dS m^{-1}) and moderately saline (8-16 dS m^{-1}) areas (5500 ha) fell under contour elevation between 0 to 25 m above MSL irrespective of season and year. Slightly (4-8 dS m^{-1}), very slightly saline (2-4 dS m^{-1}) and non-saline (0-2 dS m^{-1}) areas were associated with the land with contour elevation between 25 to 50 m and 50 to 75 m above MSL.The land use with aquaculture (169 ha; 20 per cent of TGA) was the most saline area in Aghanashini estuary. Cropped and vegetation lands were less saline than under aquaculture.

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