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Salinity Studies for Evaluation of Irrigation Suitability Status of Tsunami Affected Regions of South India

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Abstract: Tsunami affected coastal areas of Tamil Nadu, India, were investigated for soil salinity to estimate their suitability for irrigation. Due to the tsunami of December 26, 2004 and subsequent submergence of coastal regions of India the resultant salt water intrusion there has led to a significant increase in salinity in both soil and water-bodies in the regions. The present research is aimed at exploring the current status of water and soil salinity, and their possible effect on the yield of the irrigation crops. Studies were carried out between Nagapattinam to Vedaranyam, the coastal regions of Tamil Nadu (India) and the region which is reported to have one of the maximum casualties, due to the recent tsunami. The results show a variable concentration of sodium level in the salinity indicating the different degree of irrigation suitability. Contours of water salinity, soil salinity, sodium adsorption ratio (SAR) and yield percentage of crop were drawn using ArcGIS 8.0; thus generated digitized maps provide a clearer picture of the above parameters.

Key words: Tsunami, salinity, crop yield, sodium adsorption ratio (SAR), electrical conductivity (EC).

Introduction

The recent Sumatra-Andaman earthquake (occurred on December 26, 2004), like most other tsunamis was a result of undersea earthquake in Indian ocean and has been reported to have caused massive destruction in human life and enormous environmental impact. Since survival of the live-stocks largely depends on natural resources, viz. soil, water and biota (mostly floras), soil forms a natural medium for the growth of plants and water is essential for plants growth and development; it forms a basic input for crop production. Water plays a vital role in plant life. The direct environmental impacts of the tsunami are coastal wetlands, surface and subsurface water by large inflow of salt water (Das, 2005). In fact, in most of the areas the inundated saline water seemed to have unfavourably changed the soil, irrigation and drinking water and conditions for agricultural activities. Studies indicate that the coastal waters are influenced by both oceanic and terrestrial processes (Press Report, 2005). The direct seawater intrusion into pond/water storage tanks was found to have been affected by deposits of silts with sand, as the tidal wave brought sand and silt along from the coast as well as sea surface (IARI Report, 2005). There has been several studies on providing recommendation for cleaning tsunami water for reuse by specific organisations (CDC Report, 2005).

Most of the tsunami research has been confined to Stormsorge modelling, and their relationship with tsunami-prediction (Murty, 1977, 1984). Tsunami modelling involves development of numerical models for tsunami in the Indian Ocean and Simulate past tsunami events identified in the tide-gauge records and develop finite-element and fractal models for tsunami run-up simulations, and soft computing tools (ANN, Fuzzy systems, hybrid approaches) to evaluate water levels due to tsunami (Pacheo and Syke, 1992). Only recently there has been major interest in evaluation of water quality and usage pattern in post-tsunami regimes (Das, 2005).

Irrigation water contains a mixture of naturally occurring salts. Soils irrigated with this water results in

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yield loss, necessitating the need for control of salinity of the soil below a threshold concentration. However, difficulty in control of soil salinity gets aggravated with increase in water salinity, thereby warranting special care to leach salts out of the root zone before their accumulation.

The present research paper aims at evaluating the effect of irrigation water quality and irrigation soil salinity of the study area as well as in estimating current irrigation, favourable, unfavourable areas and crops, leaching requirements, evapotranspiration requirements of crops for irrigation areas and the suitable crops for sodium content in the present irrigation water in the study area affected by the tsunami (Nagapattinam to Vedaranyam).

Methodology and Need for the Study

Agro-Suitability Study of Soil

To evaluate the agro-suitability of the post-tsunami soil, with respect to the salinity, soil samples were collected at various sampling locations along the coastal agricultural tracks of the study area (along with both surface and groundwater samples at the proximity of soil-sampling site). The samples were collected for analysis on 24th September 2005. The water samples were analysed for electrical conductivity along with other water samples and the soil-salinity and other agro-characteristics of soil were estimated using methods outlined in successive paragraphs.

Evaluation of Soil Salinity

The water extract of the soil was obtained from filtration of soil-water mixture (i.e., 1:5 by weight ratio, periodically shaken with 1 hr duration of contact), added to 0.1% of sodium meta-phosphate (extract : reagent = 1:250 V/V) and the re-filtered mixture was used to estimate the electrical conductivity using a water quality analyzer. The obtained value was multiplied by 10 (a multiplication factor corresponding to silty and fine sandy clay loams) to account for the soil salinity in terms of electrical conductivity (Rhoades, 1982).

Estimation of Leaching Factor, Crop Tolerance to Salinity and Sodium Adsorption Ratio

The leaching factor was estimated based on the electrical conductivity of the water (obtained directly from water samples collected at the sampling site) as follows:

$$LF = ECw/ECe \qquad (1)$$

where LF = Leaching fraction, ECw = Electrical conductivity of water (dS/m) and ECe = Electrical conductivity of soil sample (dS/m).

The required total annual depth of the water that needs to be applied to meet both the crop demand and leaching fraction was estimated by following equation:

$$AW = ET/(1 - LF) \qquad (2)$$

where AW = Depth of the water applied (mm/year), ET = Total annual crop water demand (mm/year) and LF = Leaching fraction.

Salinity tolerance for a crop varies from crop to crop, depending upon the ability of specific osmotic adjustments by the individual crops to extract water from a saline soil. Crop yield percentage was calculated using the Mass and Hoffmans' equation (1977).

$$Y = 100 - b\,(ECe - a) \qquad (3)$$

where Y = Relative crop yield (percent), ECe = Salinity of the soil saturation extract in ds/m (associated with a designated percent yield), a = Salinity threshold value in ds/m, b = Yield loss per unit increase in salinity, which was estimated as follows:

$$b = 100/(\text{ECe at 0\% yield} - \text{ECe at 100\% yield}) \qquad (4)$$

ECe at 0% and 100% was calculated by crop tolerance and yield potential, as influenced by irrigation water salinity (ECw) or soil salinity (ECe) (Ayers and Westcot, 1994).

On rearrangement of equation (4),

$$ECe = (100 + ab - Y)/b \qquad (5)$$

Sodium Adsorption Ratio (SAR) was estimated as follows:

$$SAR = NA^{+}/(Ca^{++} + Mg^{++}/2)^{(1/2)} \qquad (6)$$

Based on requirement standards of soil and water salinity for various crops, the presently cultivated major crops of the study area were evaluated for their suitability, and recommended crops were proposed.

Geographic Information System (GIS) Mapping and Modelling

The Geographic Information System (GIS) is a computer-assisted system for acquisition, storage, analysis and display of geographic data. This tool is the best substitute for many tedious conventions. ARC/INFO is one of the complete and extensive tool available and found satisfied for most of the applications. This tool was well extracted for this study to prepare base map of the study area and contours of the water quality parameters.

Preparation of Base Map

For digitization of study area, a base map was prepared by importing to the GIS software (in tiff format) the scanned maps of land use (developed by IRS, Anna Univ.) and the topo-sheets (Survey of India) at a scale of 1:50,

000. The scanned maps were geo-referenced using the spatial data (latitude, longitude) made available from GPS for the well-defined and permanent points. The geo-referenced maps were digitised, edited for errors and linked with the attribute data.

Preparation of Contour Maps

The functionality of Arc Map included in ARC/INFO is used for plotting contours for electrical conductivity of water, soil, sodium adsorption ratio, yield percentage of paddy, ground nut, sugar cane and cotton for the water and soil samples collected from the tsunami-affected area. The steps that were followed for preparing contours for the quality parameters were as follows:

The spatial data needed as input (point data) to GIS, which denotes the location of the points where the water samples have been collected for qualitative analysis was found out using Global Positioning System (GPS). The spatial data collected were given as input to GIS along with the qualitative parameters estimated as attribute data from an external source using Add XY data of Tools command prompt of Arc Map. The point data file was exported as shape file, which is the editable format of the Arc Map software.

A contour map considering the quality parameter value as the height source was created for the shape file at regular intervals of 0.5 units using surface analysis of the 3D Analysis command prompt of Arc Map GIS. The contour maps prepared were overlaid on the base map showing the areas of inundation and are presented as output.

Results and Discussions

Increase in Water Salinity

Due to tsunami, water quality seems to be highly affected in the region of Nagapattinam to Vedaranyam. In the stretch sampling zones are Vettar River (VR), Nagore (NG), Nagore (NG1), Vadakkupoigainallur (VPN), Velankanni (VK), Prathabaramapuram (PP), Vizunthamvadi (VM), Vellappallam (VP), Tamaraipulam (TP), Pushpavanam (PV), Arkattuthurai (AKT) and Vedaranyam (VD). Figure 1 shows that the electrical conductivities of water are 13.4, 5.45, 2.59, 2.07, 1.62, 0.703, 1.23, 2.1, 1.51, 2.27, 8.81, 1.18 ds/m at 25°C respectively. As per the classification of irrigation water based on electrical conductivity (EC), the fresh water with EC 0.1 ds/m is considered excellent for irrigation, whereas the conductivity (or low saline water) is 0.1 to 0.25 ds/m and is normally suitable for all crops and soils (except extremely low permeable soils) and the water with conductivity range of 0.25 to 0.75 ds/m (medium saline water) is good for normal salt tolerant plants with preferably moderate leaching. The saline water (with conductivity 0.75 to 2 ds/m), on the other hand, is permissible for only high tolerant plants with adequate drainage requirement, whereas the agro-potential of highly saline water (having a conductivity of 2 to 3 ds/m) is doubtful and is considered bad water for irrigation. The conductivity of highly saline water is more than 3 ds/m and is thoroughly unsuitable for irrigation (Sharma & Sharma, 2002). As evident from the results, the water in the zones of VR, NG1 and AKT are unsuitable for irrigation, whereas the water in NG, VPN, VP and PV are doubtful irrigation and the water in VK, VM, TP and VD are suitable for high salt tolerant crops. In the zone of PP, water quality is suitable for irrigation, yet leaching is required. Out of the major crops cultivated in Nagapattinam (i.e., paddy, pulses, ground nut, sugar cane, cotton etc.), since paddy, ground nut and sugar cane are moderately tolerant and cotton is relatively more tolerant for salinity, the latter can be suitable for irrigation in the zones of VK, VM, TP and VD and the former can be suitable (with irrigation and leaching in PP). If proper

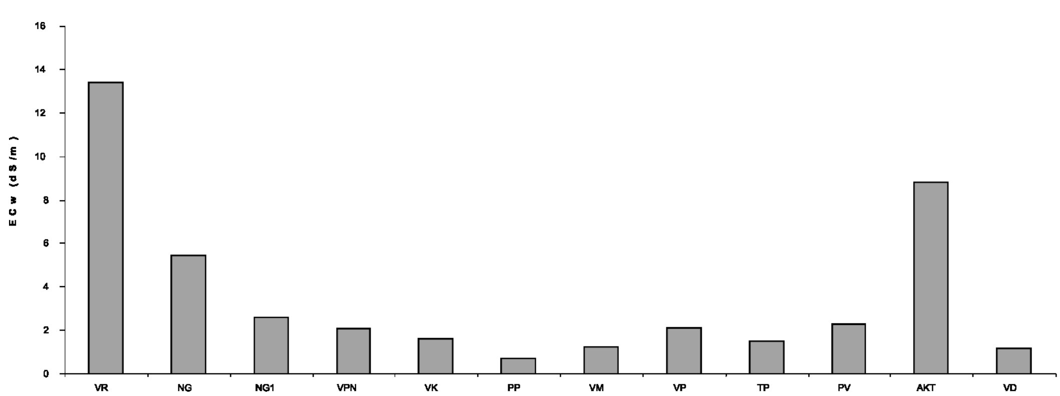

Figure 1: ECw vs location ID.

and enough leaching can be provided in the zones of NG, VPN, VP, and PV, water can also be suitable for irrigation.

Increase in Soil Salinity

For irrigation not only water quality is important, soil salinity is also more important due to the accumulation of salt from water to the soil with each irrigation. If the soil is more saline, it reduces the absorption capacity of the water. Generally the plants have response to salinity: if the EC of the soil is 0-2 dS/m that is mostly negligible amount; sensitive plants are not suitable for the soil having a salinity of 2-4 dS/m; growth of the many plants are restricted for the soil having the salinity of 4-8 dS/m; soil salinity of 8-16 dS/m is satisfactorily for the tolerant plant; and soil having the salinity of above 16 dS/m is suitable for very few tolerant plants. Figure 2 shows the sampling zones from Nagapattinam to Vedaranyam stretch: salinity of soil 5.31 dS/m for the location (VR), 3.3 dS/m (NG), 1.83 dS/m (NG1), 3.4 dS/m (VPN), 2.96 dS/m (VK), 47.9 dS/m (PP), 39.1 dS/m (VM), 49.2 dS/m (VP), 44.4 dS/m (TP), 21 dS/m (PV), 46.1 dS/m (AKT) and 32.1 dS/m (VD). From these results, NG1 having the salinity of 1.83 dS/m is negligible amount for plants growth; NG, VPN, VK location having salinity value of 3.3, 3.4, 2.96 dS/m in the soil is suitable for the plants being less sensitive to salinity; and locations of VR, VM, VP, TP, PV, AKT and VD soils having higher salinity value (i.e., above 16 dS/m) are suitable for few saline-tolerant crops only.

Current Irrigation

Generally in Nagapattinam district, paddy, ground nut, sugar cane and cotton are the main irrigation crops in addition to the other surplus crops (Viz. gingely, banana, soyabeans, tapioca and cashewnuts). For the study, these major four crops were considered. For saline soil, leaching is provided to the root zone before it is enriched to damaging concentrations. However, in the current situation, since both the water and the soil of the sampling locations are in saline conditions, the yield of the crops is expected to be adversely affected (Figures 3 and 4). Crops of paddy, ground nut, sugar cane, cotton are suitable for the locations of VR, NG, NG1, VPN and VK. VR, for instance, with the water salinity of 13.4 dS/m, is unsuitable for irrigation and with soil salinity of 5.31 dS/m, is suitable for moderately sensitive crops. Thus, in this case due to higher salinity of water and lower salinity of soil, an irrigation (current) providing a 32.2%, 68.36% and 16.42% leaching, is expected to yield 71.12% of paddy, 86% of ground nut and 31.41% of sugar cane,

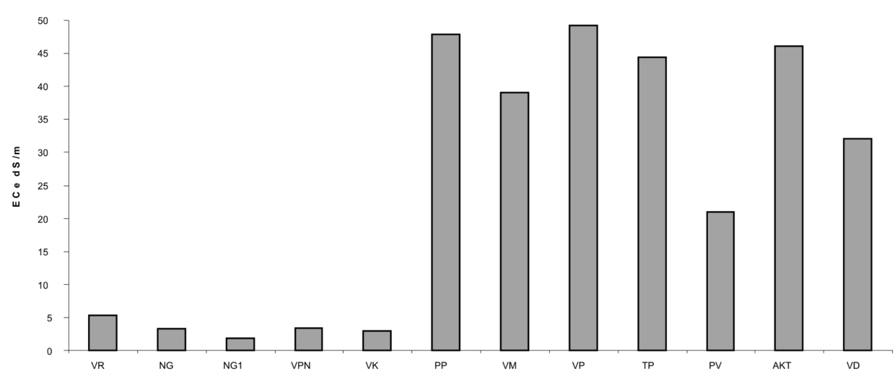

Figure 2: ECe vs location ID.

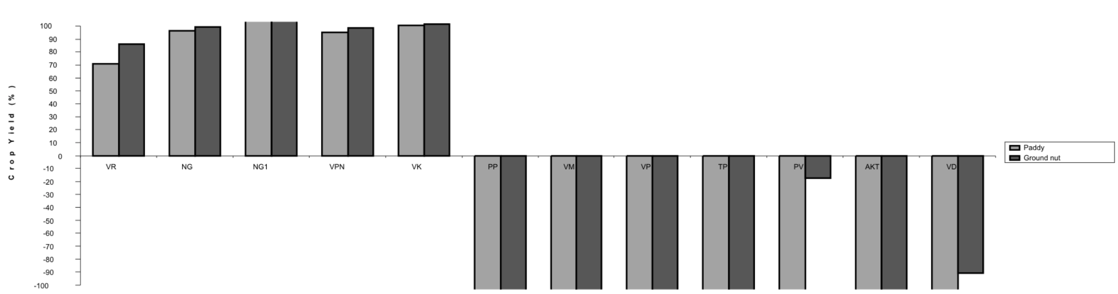

Figure 3: Crop yield percentage (paddy and ground nut) Vs location ID.

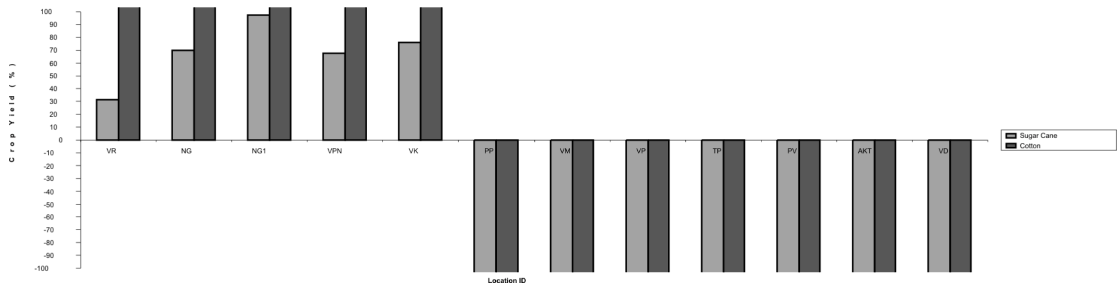

Figure 4: Crop yield percentage (sugar cane and cotton) vs location ID.

respectively. Since cotton is tolerant to salinity, it would require much less leaching compared to other crops (11.01%) for a yield of 100%.

For the location NG, with water salinity of 5.4 dS/m (unsuitable for irrigation) and soil salinity of 3.3 dS/m (not suitable for sensitive crops), paddy, ground nut and sugar cane (which are moderately sensitive to salinity) require a leaching of 10.99%, 19.78% and 6.08%, for a yield of 96.25% of paddy, 99.40% of ground nut and 66.79% of sugar cane, respectively. In this area, for salinity-tolerant crop cotton, the leaching requirement is 4.2% and the yield is 100%. In the location NG1 (water salinity 2.59 dS/m and soil salinity 1.83 dS/m), on the other hand, proper leaching can make suitable for crops of paddy, ground nut, sugar cane and cotton to give a yield of 100% of paddy, 100% of ground nut, 97.53% of sugar cane and 100% of cotton (required leaching proportion being, 4.94%, 8.5%, 2.8% and 1.9% respectively).

For the location of VPN (water salinity 2.0 dS/m; the soil salinity 3.4 dS/m) low soil salinity than the water salinity can cause an initial accumulation of salt unto the soil, and is suitable only for moderately tolerant crops (viz. paddy, ground nut and sugar cane, with a yield of 95%, 98.68% and 67.7% respectively by providing a leaching of 3.9%, 6.6% and 2.2%, respectively) and the tolerant (namely, crop cotton to yield 100% by providing 1.5% of leaching). The location of VK (water salinity 1.62 dS/m is good, soil salinity 2.96 dS/m), in the same way, is unsuitable for sensitive crops and can be used only for salt-tolerant crops (paddy, ground nut, sugarcane and cotton) to yield 100% of paddy, 100% of ground nut, 76.06% sugar cane and 100% of cotton, by providing a leaching of 3%, 5.1%, 1.7% and 1.2%, respectively.

Although paddy, ground nut, sugar cane and cotton are favoured (with suitable leaching) in much of the study area, yet even these salt-tolerant crops are not favoured by PP, VM, VP, TP, PV, AKT and VD, where both the soil and water salinity are rather high (thus, ruling out the possibility of irrigation, at present state of water quality, because of inability of the crops to absorb the irrigated water).

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio measures the relative concentration of sodium to calcium and magnesium. High sodium ion in water affects the permeability of soil and causes infiltration problems; sodium in soil in exchangeable form replaces calcium and magnesium adsorbed on the soil clays and causes dispersion of soil particles and the soil becomes hard and compact when dry and reduces infiltration. Excess sodium in water can lead to crusting the seed beds, temporary saturation of the surface of the soil, high pH, soil erosion and inadequate nutrient availability. Sodium adsorption ratio (SAR) in irrigation water varying between 2 and 8 makes the water suitable for very sensitive crops; whereas water with SAR of 8-18, 18-46 and 46-102 are suitable for sensitive crops, for moderately sensitive and for tolerant crops, respectively. As per Figure 5, in NG the SAR value is 9.67 indicating its suitability for irrigation except for very sensitive crops. In the location VR, the SAR value is 21.18 indicating only moderately sensitive crops suitable for irrigation. In all other locations the SAR values indicate the water suitable enough for irrigation even for sensitive crops.

Evapotranspiration

Irrigation water can enter into the soil to contact with the crop root system. In it soil removes some amount of water by evaporation and plant surface removes water by transpiration and, therefore, is called Evapotranspiration. For the crops of paddy, ground nut, sugar cane and cotton, the total depth of the water required to attain its maturity is respectively 150, 45, 90 and 40 cm and ET values of the crops and locations are shown in Figure 6. From the results evapotranspiration requirement for paddy > ground nut > sugarcane > cotton; it shows that moderately sensitive salinity crops of paddy, ground nut and sugar cane requires more ET to attain its maturity while salinity-

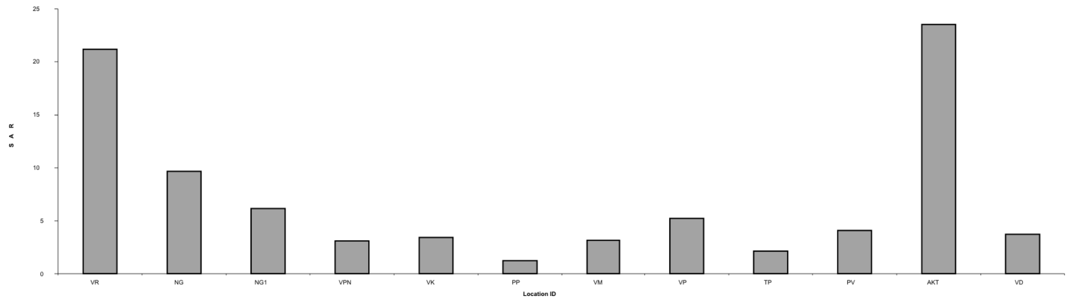

Figure 5: SAR vs location ID.

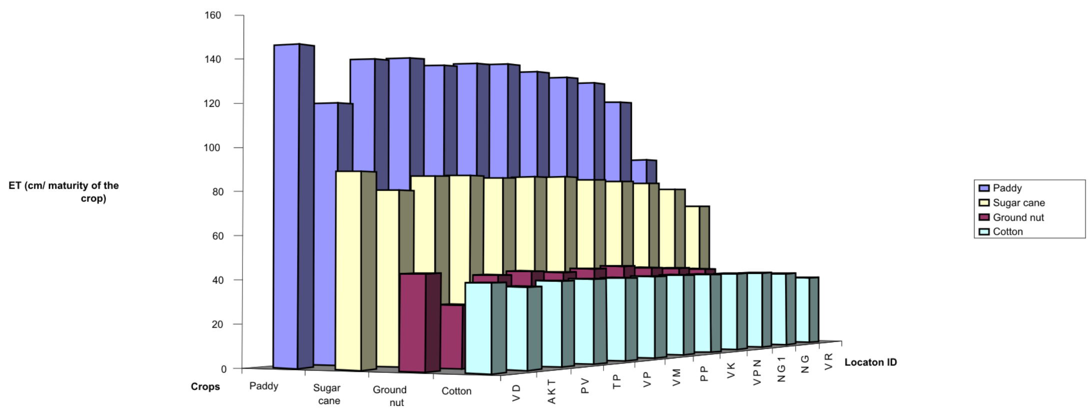

Figure 6: Evapotranspiration vs location ID.

tolerant crop cotton requires less ET and ET is proportional to yield of the crop.

GIS-digitized Base Map with Location

Figure 7 shows the location of the sampling points. The area corresponding to the numbers mentioned in the map are as follows:

(1) Vettar River (VR), (2) Nagore (NG) and Nagore (NG1), (3) Vadakkupoigainallur (VPN), (4) Velankanni (VK), (5) Prathabaramapuram (PP), (6) Vizunthamvadi (VM), (7) Vellappallam (VP), (8) Tamaraipulam (TP), (9) Pushpavanam (PV), (10) Arkattuthurai (AKT) and (11) Vedaranyam (VD).

GIS-based Water Salinity Contours

Figure 8 shows the variation of water salinity in the study area. The distinct colour of the contours represents different values of salinity and they are given in the legend of the map.

The salinity value near the VR is relatively high which can be clearly inferred from the contour and a decreasing trend can be seen towards the south from VP to PP. From VM to PV there is a random change in the colour which suggests that there is a random change in those areas. The trend near AKT is much similar to that seen in VR and again colour change of the contour shows the low level salinity in VD.

GIS-based Soil Salinity Contours

Figure 9 shows the soil salinity of our study area. From VR to VK contours of different colours show that the concentration of soil salinity is low. It shows the irrigation suitability of the corresponding locations. This indicates the importance of soil salinity. From PP to VD colour of the contour indicates the concentration increase in soil salinity of the corresponding locations which in turn affects the irrigation.

GIS-based SAR Contours

Figure 10 shows north to south of our study area a violet colour contour indicating the higher SAR value in the location VR and in the map for low level SAR were found from NG to PP that is represented in different colours of contour. Random change in colours of contour in the location VM to PV inferred random changes in SAR. Fluorescent colour contour of AKT shows the higher value of SAR in our study area and immediate change in the contour colour represents the lower SAR value in the location VD.

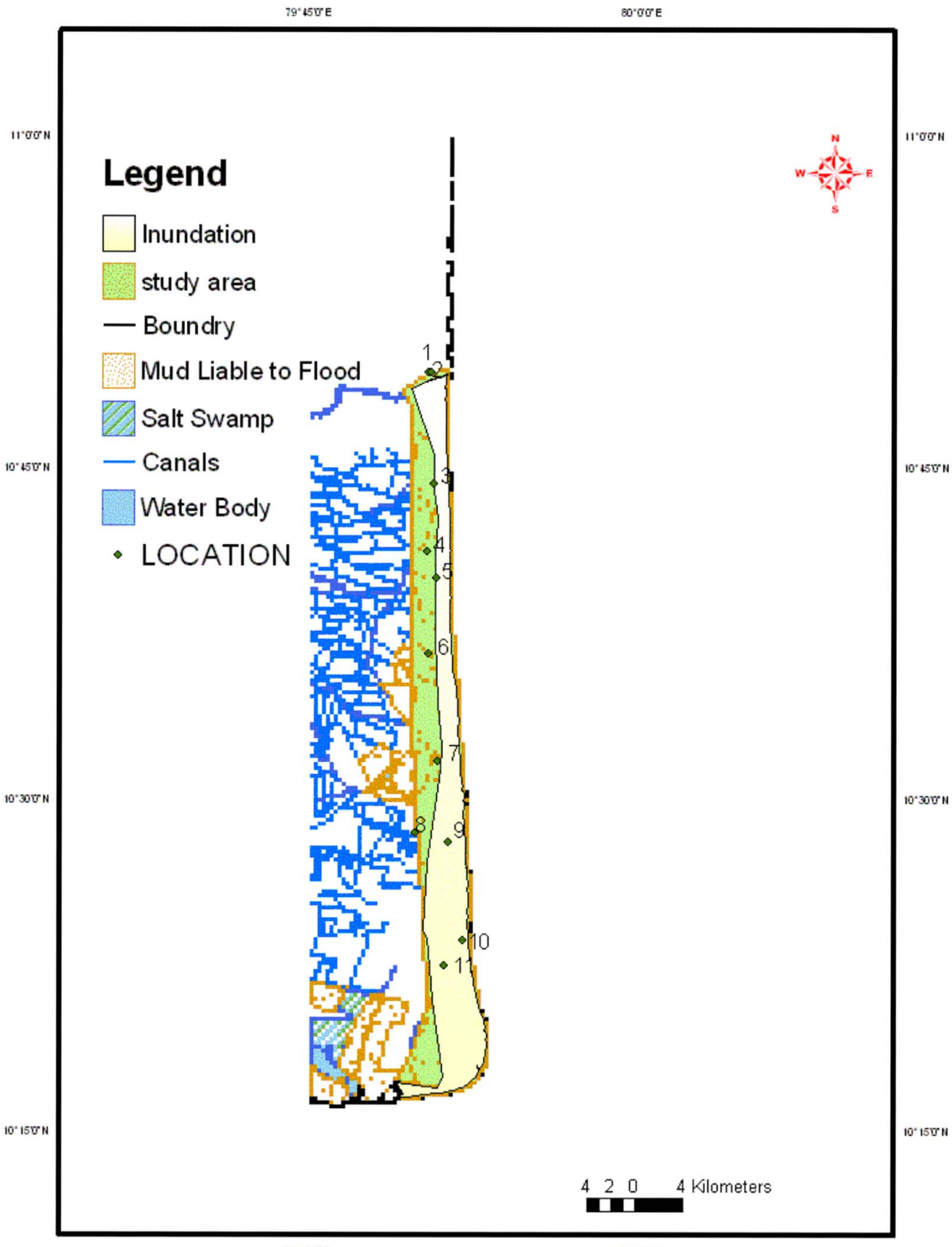

Figure 7: Locations in study area.

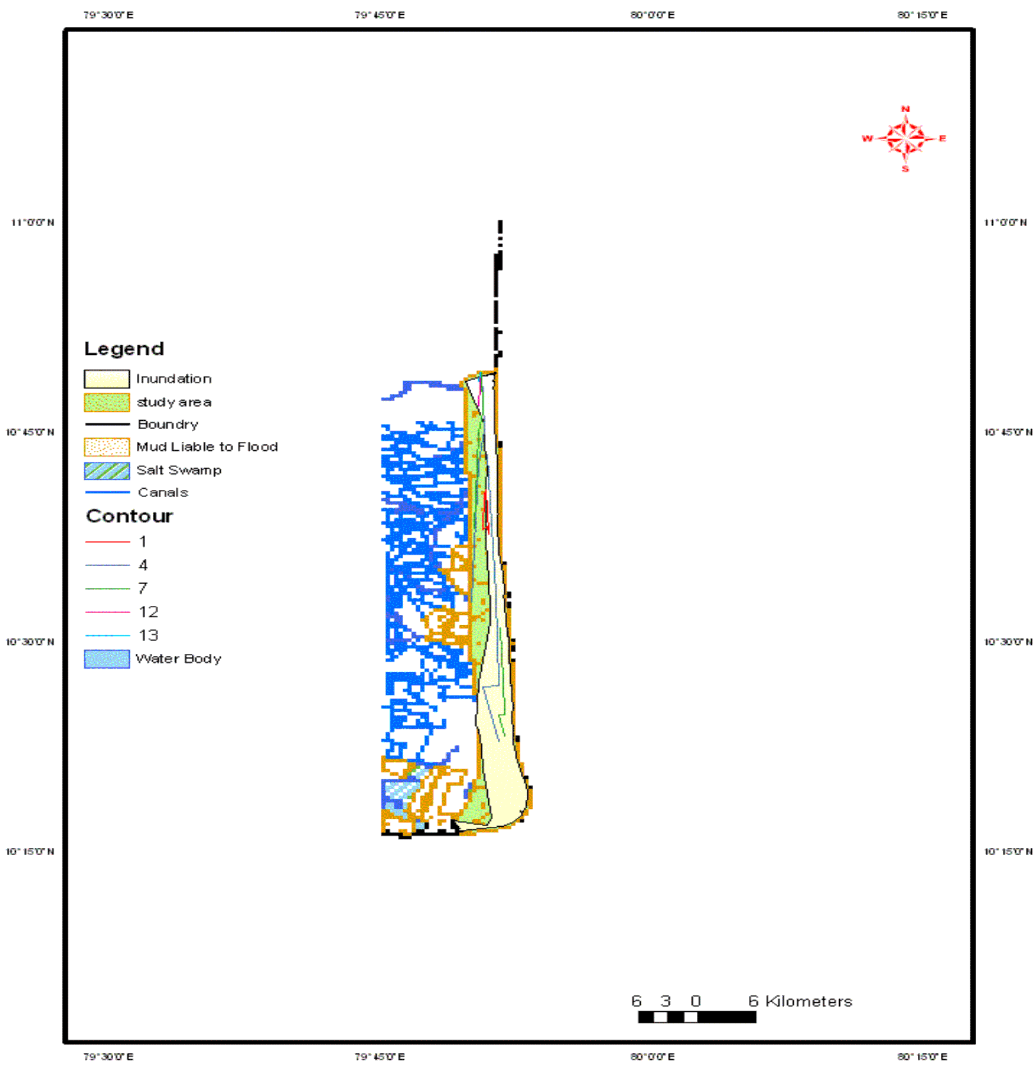

Figure 8: Contour map of ECw in the study area.

GIS-based Yield Percentage Contours

Figures 11, 12, 13 and 14 show yield percentage of paddy, ground nut, sugar cane and cotton for the locations of VR, NG, NG1, VPN and VK depicting linear increases in yield represented in different colours of contour i.e dark blue, fluorescent and red. The change in colour of the contour in VPN indicates the slight decrease in yield percentage and again increase in yield is represented in VK for paddy, ground nut and sugar cane. For cotton yield percentage is uniform for all the above locations, and contour is represented in single colour. Except the above locations PP, VM, VP, TP, PV, AKT and VD are unsuitable for irrigation so there is no contour on those areas.

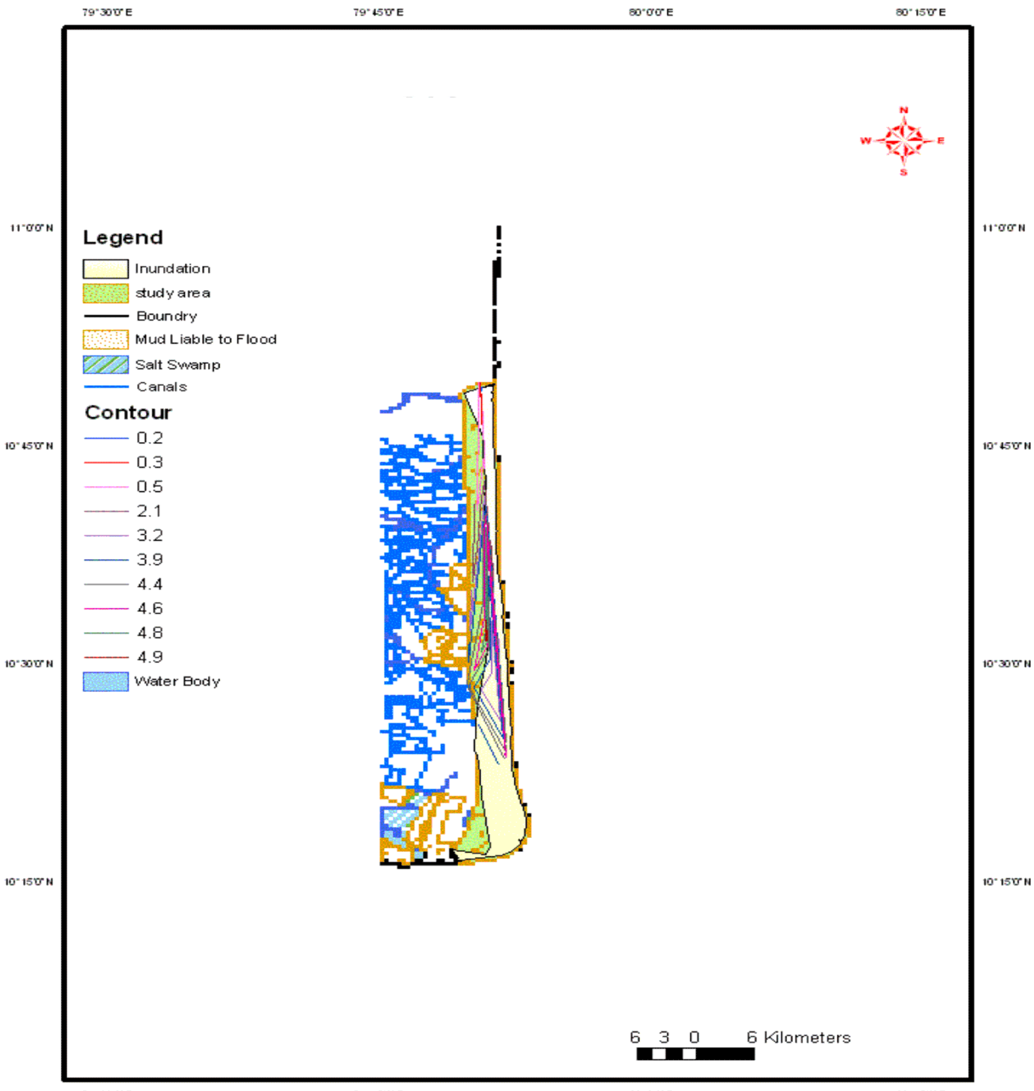

Figure 9: Contour map of ECe in the study area.

Conclusion

From agro-suitability study, it was observed that in the current irrigation favouring zones Vettar River and Nagore, respectively water salinity is more and soil salinity is comparatively low. Thus irrigation may not be much beneficial for the crop yield, whereas in the locations of Vadakkupoigainallur and Velankanni water and soil salinity are low, providing a suitable leaching that is expected to result in a good yield. In the locations of Prathabaramapuram, Vizunthamvadi, Vellappallam, Tamaraipulam, Pushpavanam, Arkattuthurai and Vedaranyam both the water salinity and soil salinity are too high indicating nonfeasibility of leaching and need of heavy rainfall to bring about reduction in the saline level in water. The sodium absorption ratio also shows better stabilization temporarily. As of now, in most of the zones of study area salt-tolerant plants, such as paddy, ground nut, sugar cane and cotton may be expected to yield better productivity (with suitable leaching).

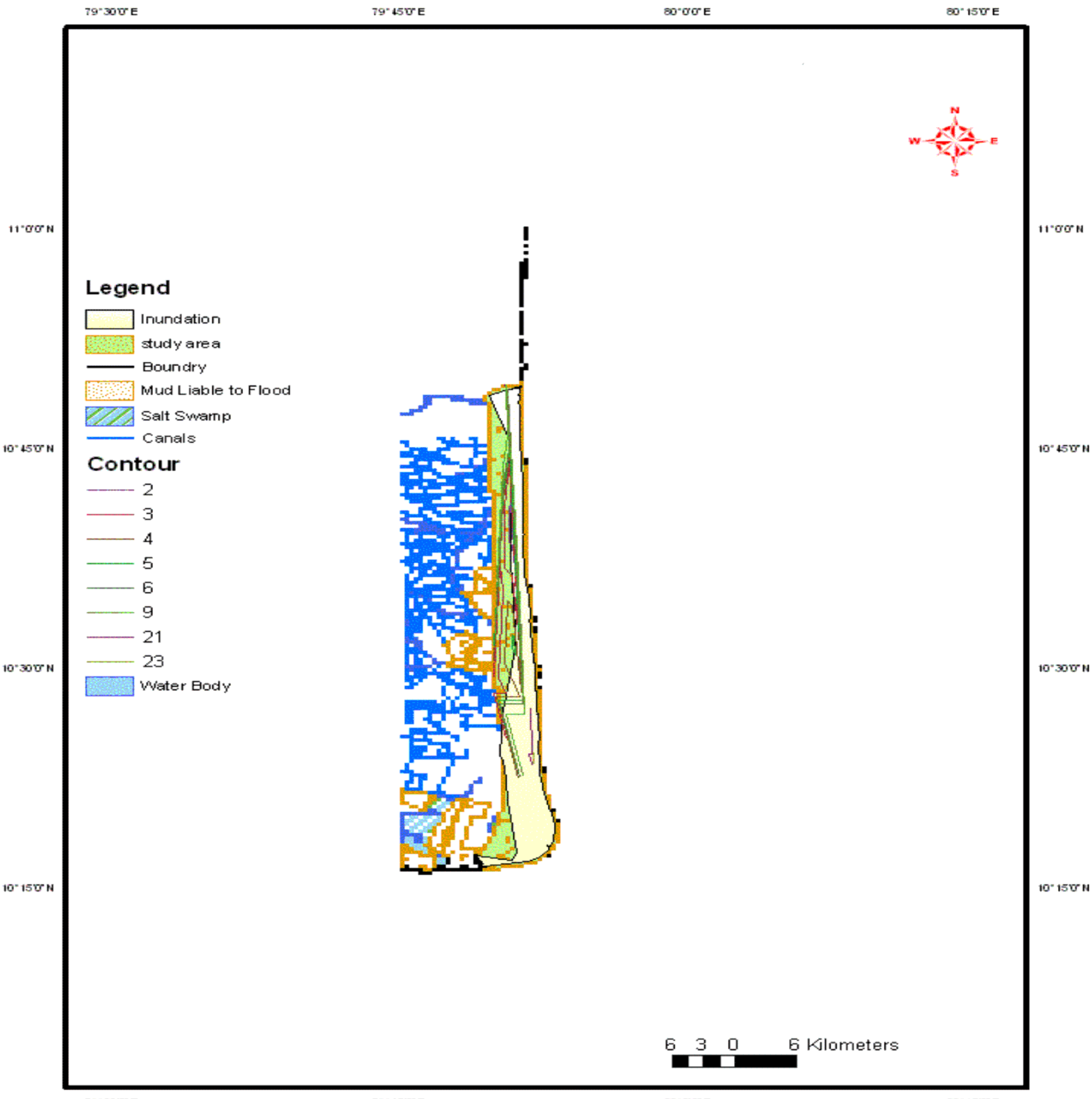

Figure 10: Contour map of SAR in the study area.

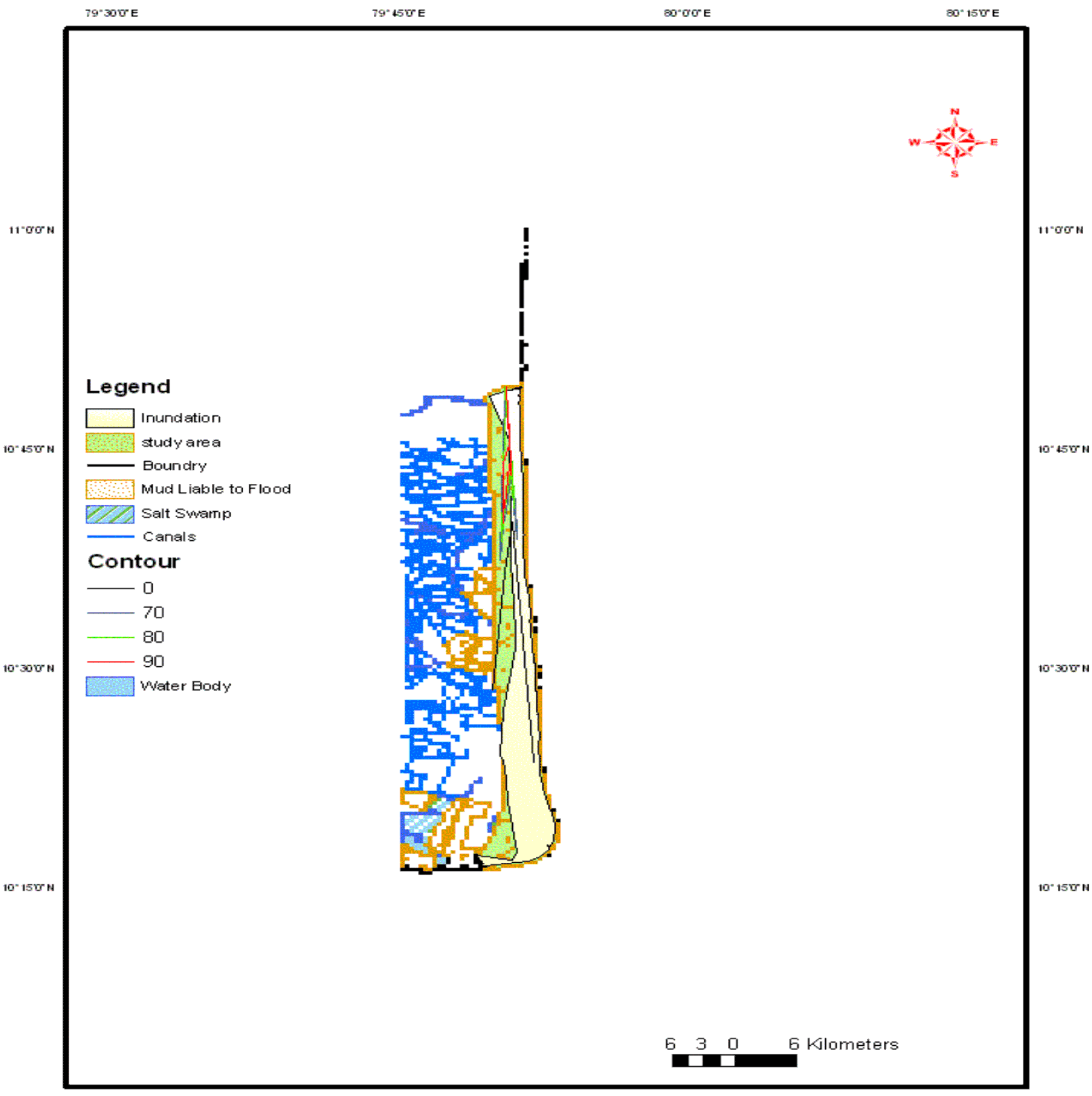

Figure 11: Contour map of paddy in the study area.

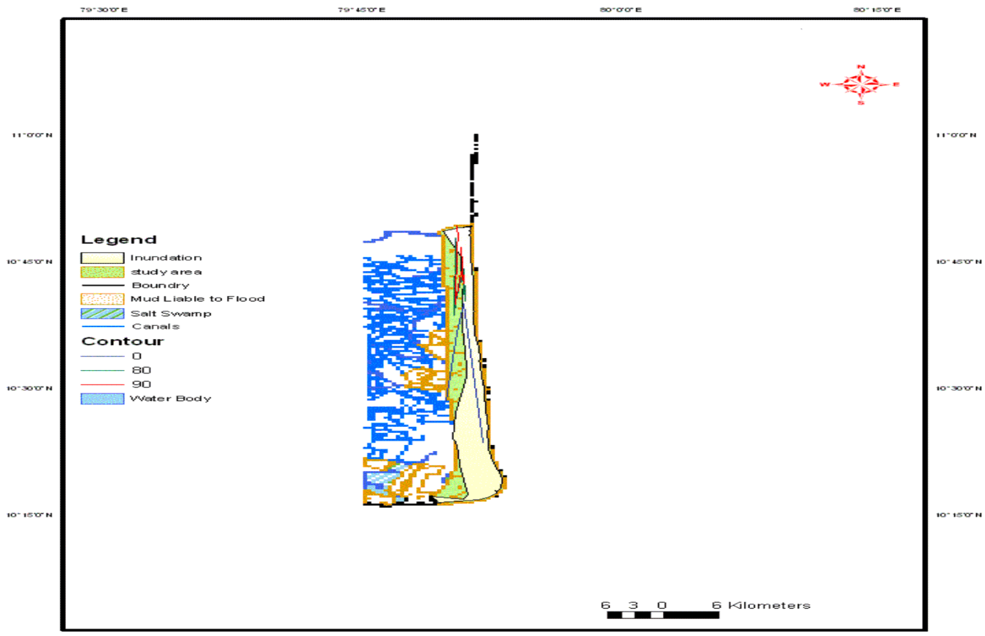

Figure 12: Contour map of ground nut in the study area.

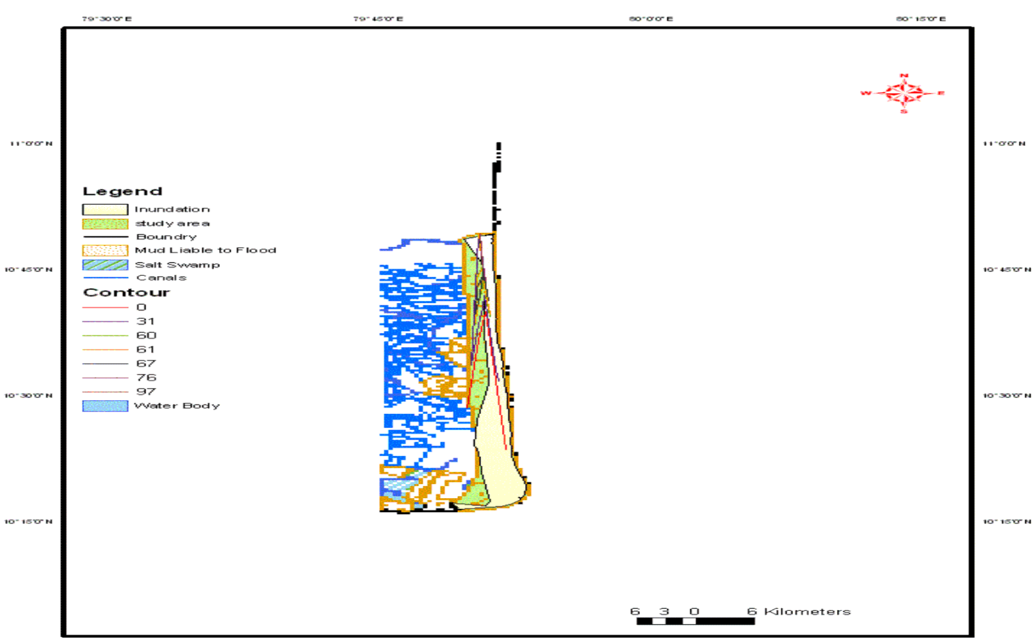

Figure 13: Contour map of sugar cane in the study area.

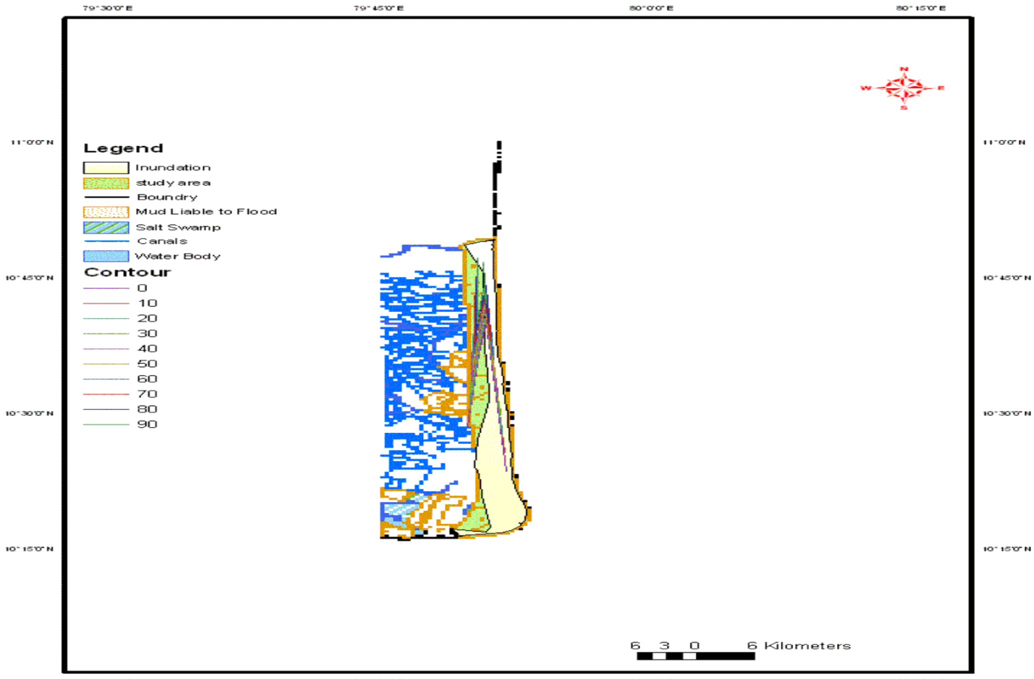

Figure 14: Contour map of cotton in the study area.

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Geology and Evolution of the Indian Plate

(From Hadean to Holocene - 4 Ga to 4 Ka)

S.M. Naqvi

Year of Publication: 2005 • Pages: 496

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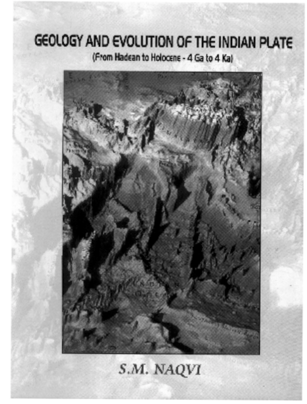

This book is divided into 22 chapters and covers Geology and Evolution of rocks from India, Pakistan, Bangladesh, Nepal, Bhutan, Sri Lanka, Madagascar and Myanmar. It has exclusive coverage of Precambrian, Palaeozoic, Mesozoic and Cenozoic rocks of the continental and oceanic parts of the plate. Position of India and its adjoining parts in Gondwana, Rodinia and other super continents are discussed at length. The book provides details of the birth of the Indian Ocean and death of Tethys when Himalaya developed from Proterozoic to Holocene, faster uplift of Himalaya, recent development of Indo Gangetic plains, Thar deserts and Deltas of the major rivers and their fans. The present book synthesizes the work done on Indian Plate especially after the acceptance of Theory of Plate Tectonics and provides a perception of the present state of knowledge and the glaring gaps. It provides an integrated interpretation of available geological, geochemical and geophysical data in terms of evolution of Indian plate from 4 Ga to 4 Ka.

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