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Study on Landforms and Soils of Krishna-Godavari Delta Using Remote Sensing

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Abstract: *Indian coastal regions have productive wet lands as also lands infested with problems of waterlogging, salinity, backwater swamps and marshes. Study and mapping of the land systems, expressive of landform, slope, soil and land use, for understanding of the associated potentialities and problems are necessary for planned development of coastal areas. Remote sensing application in the study of land systems of Krishna and Godavari delta areas of Andhra Pradesh facilitated identification of three major land systems, namely (1) Sea system, (2) Coastal system, and (3) deltaic system, and 20 associated sub-systems. Soils associated with these land systems were established by limited field studies and their spatial distribution extracted from systematic interpretation of RS imagery. Major soil formations in the area are coastal sand (Psamments), Deltaic alluvium (Fluvents, Aquents, Aquepts, Usterts), red loamy soils (Ustalfs), black soils (Usterts) and saline-sodic soils (Orthids, Ustalfs). This study has particularly brought out the problems of coastal environment including the problematic soils leading to strategies for their reclamation.*

India has a long coast line of about 6000 km with high production potential. The problems of resources evaluation and management in the coastal region are strikingly different than those of the hinterland. The eastern coastal belt, in particular, contains highly productive wet lands with problems of waterlogging, salinity, backwater swamps, and the like.

Study and mapping of coastal landforms are necessary for understanding coastal processes operating in the area towards their optimal management.

Several studies have been carried out on coastal environment, but the information on land systems with particular reference to soils and their degradational problems is rather scant.

Babu (1975) studied geomorphological evolution of Krishna delta for specific objective of identification of prospective hydrocarbon reservoirs. Bhattacharya (1983) studied the geologic and geomorphic controls in landuse pattern in Godavari delta using Remote Sensing techniques and discussed landuse of fluvial and marine landforms. Sahai (1985) illustrated the utility of Landsat imagery for coastal environmental studies and asserted the level of expertise developed.

STUDY AREA

The study area comprising part of Krishna-

* All India Soil and Land Use Survey, New Delhi-110 012.

Godavari delta extends over Andhra coast from Ongole to Machilipatnam, on both the sides of the river Krishna. Geographically, the area lies between 15°13' to 16°30' E Long. and 79°57' to 81°24' N Lat. and is covered by Survey of India topographical map Nos. 65 D & H and 66 A & E. The north-western boundary touches the Madras- Calcutta grand trunk road passing through Vijaywada and Eluru, and the eastern boundary roughly follows the eastern bank of Kolleru lake dipping vertically down touching Bay of Bengal.

Administratively, the area falls in the jurisdiction of Prakasham and Guntur districts on the south of Krishna, and Krishna and West Godavari districts on the north.

The study area merges with the undulating plain and the low hill ranges of the outlying spurs of the Eastern Ghats. It covers an area of 384 sq. km spread over 122 villages. The delta is nearly flat with unculturable swamps; at places in the vicinity of coast line.

The geological succession of the area comprises alluvial deposits (Recent period), Deccan trap (Eocene), Gondawana (Carboniferous), Cuddapah-Kurnool and Dharwars (Cambrian) and granite-gneisses (Archaean).

The area receives rainfall both in south-west and north-east monsoon periods. West Godavari district receives more annual rainfall than Guntur and Krishna districts having 1160 mm, 954 mm and 973 mm, respectively. The Praksham district is a drought-prone region receiving around 750 mm rainfall.

MATERIALS AND METHODS

Landsat data in the form of black and white imagery in individual MSS bands 4, 5 and 7 and false colour composites (FCC) in the scale of 1:500,000 were used for visual

TABLE 1. Particulars of Landsat data used

Products	Path	Row	Month	Year	Bands
F C C	152	49	June	1977	4,5,7
	152	49	January	1973	4,5,7
	153	49	May	1977	4,5,7
			January	1977	4,5,7
Black and	141	49	September	1982	2,4
white	142	49	September	1983	2,4
	142	49	November	1985	2,4

interpretation. The details of path, row and dates of passes are given in table 1.

A base map with relevant physical and cultural features was drawn from the Survey of India topographical maps of 1:250,000 scale and reduced to 1:500,000 to correspond with the scale of the available imagery.

Landsat-MSS FCCs were interpreted monoscopically with the aid of magnascope for differentiation and categorisation of: (1) sea, coastal and deltaic systems, (2) landforms, (3) landuse, and (4) soils and degraded lands such as salt-affected, marshy and swampy.

Sample areas were marked deploying stratified sampling technique and transferred on to the topographical maps. Four sample areas together covering about 4000 ha were selected for detailed studies.

Ground truth data collected at high intensity level from the sample areas were supplemented by random sampling from various mapping units. Six soil profiles were studied in detail, and morphological characteristics recorded. Representative soil samples were analysed in the laboratory for physical and chemical characterisation of the soils. In addition, 29 auger bores were examined and 52 site observations made for checking land use details. Soils were classified according to the USDA Soil Taxonomy.

The mapping legend was then correlated with ground truth data and the soil cum landform/landuse map prepared (Fig.1). The mapping units were translated into soil and landuse classes (Tables 2&3).

RESULTS AND DISCUSSION

Visual interpretation of Landsat data revealed three major systems, viz. Sea System, Coastal System and Deltaic System. Based on varying image characteristics, the major coastal systems were segregated into 20 units. The details of image interpretation key, ground checked land systems, landuse/land cover and site characteristics are furnished in table 2.

Based on the profile studies, supported by auger observations and study of natural cuttings, five broad soil groups (Traditional system) representing ten subgroups (USDA 1983) and their associations have been identified in the study area. The details are presented in table 3.

The variations in the density of blue colour depicted in the imagery (prussian and deep blue) allowed seperation of two sea systems, relevant to the sea depths and sediment concentration. Correlation with sea contours of topographical maps revealed that the shallow sea (SS) corresponds to 50 metre depth contour. The recurved spits (RS) and relic lagoons (RL) of coastal systems suggest the plausible expansion of coast line into the shallow sea in course of geological times.

The coastal system is prominently expressed in the Prakasham and Guntur districts on the right bank of river Krishna. The Krishna left bank shows coastal imprints

TABLE 2. Mapping legend, related landforms, associated soils and landuse

Sustems & landforms	Mapping Unit	Imagecharacteristics	Soils	Landuse/ Land cover
1	2	3	4	5
SEA SYSTEM				
Shallow sea	ss	Smooth prussian blue (whitish tinge)	--	--
Deep sea	DS	Smooth deep blue	--	--
COASTAL SYSTEM				
Brsvh	B	Smooth, whitish, narrow, occasionally bluish strip along the sea	Typic Quartzipsamments	Barren
Recurved spit	RS	Shining red within the sea	Aquic Ustipsamments	Mangrove
Coastal dunes	CD1	Smooth, medium pink	Typic Ustipsamments Typic Quartzipsamments	Casuarina Forest & cultivated
Coastal dunes	CD2	Coarse, whitish with scattered pink	-do-	Wasteland scattered casuarina forest
Swamps	S	Smooth, medium to dark bluish grey	-	Wasteland
Mudflats	SM	Smooth, shining deep red with occasional fine white mottles	Vertic Haplaquepts	Mangrove
Mudflats	SS	Coarse, faint pink with Whitish mottles	Aquic Salorthids	Salt tolerant Saliconia sp.
Plain	CP	Coarse, light to dark pink on whitish base and bluish patches, abrupt naturally distinct	Aquic Ustortents Typic Halaquepts	Partly culti- vated, fallow
Salt affected	CS	Smooth, light greyish and pinkish along the coast	Typic Salorthids/ Typic Halaquepts/ Aquic Natrustalfs	Wasteland

Contd.....

1	2	3	4	5
Relic lagoon	RL	Coarse, medium grey, alternate linear strips within the coastal plain with pink mottles	Aquic Ustipsamments/ Vertic Haplaquepts	Cultivated/ fallow
DELTAIC SYSTEM				
Low land	L	Smooth, bluish medium gray with very light tinge of pink, nroad linear patches	Aquic Ustifluvents/ Vertic Ustochrepts/ Typic Haplaquepts	Cultivated
Plain	P	Smooth red and pink with Patches of medium blush grey	Entic Chromusterts/ Typic Chromusterts/ Typic Pellusterts	Cultivated
Degraded plain	DP	Coarse, whitish grey in association of foot-hills	Typic Chromusterts/ Aquic Ustorthents	Wasteland
Relic butte	RB	Localised, faint yellowish with black streaks	Typic Ustorthents/ Rodic-Udic Paleustalfs	Fallow/ wasteland
Kolleru Lake				
Water body	K	Smooth, blur	--	Water
Vegetated	Kv	Smooth, pink	--	Reeds/other Vegetation
Shore	KS	Corse, light grey	Typic Ustipsamments	Partly cultivated
Shore	KSP	Smooth, red	Typic Ustorthents Aeric Haplaquepts.	Plantation

TABLE 3. Soil associations encountered in study area

Broad soil group	Subgroup	Soil family*
Coastal sand	Typic Ustipsamments/ Quartzipsamments	Sandy, mixed/quartzitic
Deltaic alluvial soils	Aquic Ustifluvents	Fine loamy over coarse loamy, mixed
	Association of Aeric Haplaquents/Vertic Haplaquepts	Clayey, mixed
	Association of Typic Pellusterts/ Chromusterts	Fine, montmorillonitic
Red loamy soils	Udic Paleustalfs	Fine-loamy, mixed
Black cotton soils	Typic Pellusterts	Fine, montmorillonitic
	Typic Chromusterts	
Saline-alkali soils	Typic Salorthids	Clayey, montmorillonitic,
	Aquic Natrustalfs	Fine loamy, mixed

* Isohyperthermic temperature regime is common

upto the shore of Kolleru lake. The inland extension of coast, both old and new, is from 8 to 35 km as shown by broken dark lines equivalent to oldest coass line or beach ridge. The presence of relic lagoon features, off shore bars and spits alongwith straightened shoreline are all diagnostic features of shore lines of emergence. The coastal system encompasses the beach (Sandy), spits, coastal dunes (Psamments), swamps (Aquic soils), mud flats (Haplaquents/ Haplaquepts), coastal plain (Ustifluvents/Pellusterts/Chromusterts) salt - affected areas (Salorthids/Natrustalfs) and relic lagoons. Identification and delineation of these landforms and their soil scapes enable reliable deduction about the potential areas that can be developed into productive agricultural Lands with measures for drainage control. Delineation of waterlogged and salt-affected areas (mudflats, swamps and lagoons) help planning for reclamation measures to restore such areas for productive purposes.

The deltaic system of Krishna river is marked by two main mouths or distributaries of which the right main distributary finally bifurcates into three smaller mouths characterised by highly irregular

Figure 1. Landsat FCC of Krishna-Godavari delta & environ.

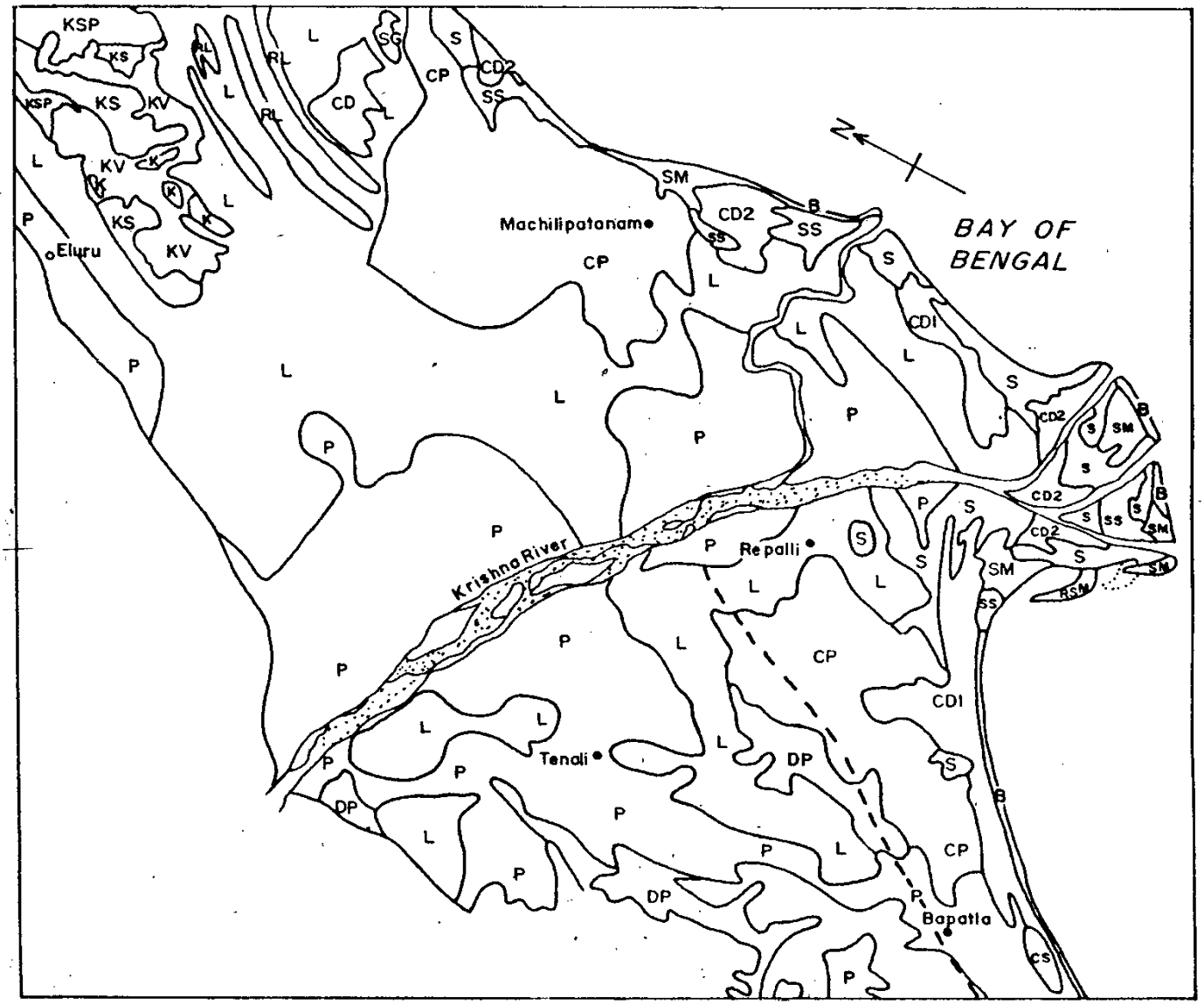

Figure 1. Land systems and landforms in Krishna-Godavari delta
(For details vide table -2)

and protruding shorelines and lower lateral continuity of sands. The studies revealed that the deltaic system is still in the process of construction and reconstruction. The former process is active at the margin of the bay by deposition of fluviatile sediments, whereas the latter could be witnessed in the highlying banks followed by somewhat depressional lands. These two forms are well picked up in the May-June imagery and are reflected by characteristic tonal and land-use patterns. Some localized areas in the right bank of Krishna are identified as relic buttes and degraded plains in the transitional areas. November, 1985 imagery enabled additional detection of some abandoned channels.

In order to understand the deltaic process, it was considered worthwhile to locate the points at which the river showed its first and subsequent bifrurcations before entering into the sea. This is related to the stream gradient from the alluvial plain to the deltaic plain. Near this point, the major course of the river begins to transport heavy silt loads, and as a result bifurcates into major distributaries to form subareal deltaic plain. The first distributary takes off at about 40 km, followed by second and third distributaries at a distance of 17.5 km and 12.5 km, respectively, in the present day Krishna river course. Considering the shifting of river courses into successive distributaries due to delta progression into sea, a three stage development could thus be assumed in the Krishna delta.

The deltaic soilscape typically comprises Aquic Ustifluvents, Vertic Ustochrepts, Typic Haplaquepts, Aquic Ustorthents, Typic Chromusterts and Udic Paleustalfs (Table 3).

Under coastal system above, one significant observation has been described about the old coast line shown as thick dotted line in figure 1. The evolution of the first distributary of the Krishna lies about 8-10 km below this old coast line or beach ridge. This observation is in agreement with the innermost shoreline identified by Babu (1975) in his studies on Krishna delta. Later shore lines 2 and 3, however, could not be located on the imegery. This possibly may be due to intricately mixed signatures of coastal and deltaic systems.

The coastal zone ranging from 8 to 35 km width displays older and younger ridges, and indicates changes in the orientation of former shore lines roughly parallel to the present day shore line. It can be attributed to the fall in the sea level by a combination of processes like crustatic movement, land movement and change in supply of sediments. The presence of various coastal and deltaic landforms attest these changes.

Coastal and Deltaic Landforms

Beaches: The zone extends almost along the Bay of Bengal as a thin whitish or bluish white, easily recognizable consistent zone on the imagery of 1973 and 1985. Such a consistency of a permanent nature is always attributed to a prograding shore line advancing seaward. It also occurs as delta front sands.

Recurved spit: It is conspicuously seen along the extreme right mouth of Krishna distributary showing upward and landward growth. Certain drift and significant growth appears to have taken place over the period from 1972 to 1985. Its position as indicated on topographical map appears as clusters of fine dots on FCC and corresponds with the definition of a spit (Evans 1942) as: 'a ridge or an embankment of sediment attached to the land at one end and terminating in open water at the other end'.

Coastal dunes: These are extensive features along the coast and could be picked up by coarse relief expressions. These could be subdivided further on the pattern of vegetation into medium to dense or sparse type.

Swamps and mudflats: These are easily recognised with medium to dark bluish grey tone on the imagery. These are low lying areas occupied by muddy stagnant water. Certain areas on slightly higher elevation support mangrove forest and still higher lands display salt tolerant *salicornia* and associate species.

Coastal plain: It is extensive on the left bank of Krishna and almost touches the Kolleru lake. It is dinstinct by its light to dark pink tone on the whitish base. Some bluish patches encompass this vast plain.

Salt-affected lands: The leeward depressional areas with smooth, light greyish and pinkish tones have problems of salts and high ground water table.

Relic lagoons: These occur as linear narrow strips in the coastal plain with medium grey tones. The word lagoon is loosely used to indicate old back-dune depressions presently filled up by finer materials.

Deltaic low lands: These occur as broad, winding, linear or irregular strips having bluish medium grey tones with light pink tinge. Locationally, they lie away from the river Krishna and predominantly have very dark greyish brown, fine clayey, cracking, regur soils.

Degraded deltaic plain: These are localised in Guntur and Prakasham districts with coarse, whitish grey tones below the foothills or along the rivulets indicating degradation due to erosion.

Relic buttes: They are localised and could be picked up by faint yellowish tones. At places rock exposures with shallow soils are encountered.

Kolleru Lake

The Kolleru lake is well picked up in the imagery. Adopting lake boundary on Survey of India topographical map, areas under water shown as K, and areas infested with reeds and other vegetation are delineated as KV units. Bare, coarse light grey areas along the margins of the lake are shown as lake shore under the unit KS. The eastern shore falling in West Godavari district, however, shows smooth, red colours due to abundance of plantation and cultivation. The presence of old coast line in its southern border suggests that the genesis

of this lake may perhaps be linked up with the fall in sea level or so.

Management Needs

Although the abstraction level of the coarse mapping on 1 : 500,000 scale does not permit specificity in formulating management plan, broad generalities for the area as a whole are indicated on the basis of landforms, associated soils, existing land uses, and problems of the area.

The major problems of the area are frequent floods, cyclone remissions, coastal dunes and sandy plains. The effect of cyclones and floods is more pronounced in serious damage to crops. Coastal dunes and sandy plain areas are therefore needed to be placed under permanent vegetal cover. Casuarina plantation in strips at right angle to wind directions will help to retard wind velocity and regulate the path of cyclone on settlement-free zones. The problem of storm surge and winds at lower levels could be tackled by plantation of low height, dense grown vegatation on lower and degraded plains with Haplaquents and Ustorthents. Cashewnut could be one such type with commercial value. Cultivated flood prone areas call for change in cropping pattern in favour of short duration varieties.

Rice grown in poorly drained areas, particularly on low lands with Haplaquents, Haplaquepts and Paleustalfs, is generally found to be subjected to toxic effects of reduced products such as Fe^{++}, Mn^{++}, S^{--}, etc. in the root zone, which is more pronounced when large quantities of fertilizers containing sulphates are applied. The reduced products when present in large quantities prove to be toxic. Some, like hydrogen sulphide and butyric acid, act as respiratory inhibitors preventing uptake of nutrients, while others like Fe^{++} and Mn^{++}, interfere with absorption and translocation of phosphorus (Mitsui, 1954). It was suggested that when a crop is affected, the field should be flooded, soil stirred up by working with a hoe and water drained out to allow the field to dry to develop small surface cracks. This is followed by fresh water leaching. Green manuring and application of heavy doses of organic manure are some of the control measures followed to improve drainage and prevent toxicity.

Saline sodic soils need suitable amendments and leaching. Experiments conducted in other coastal areas have shown that field bunding, subsurface drainage and mulching the fallows with rice husk after crop harvest appreciably control soil salinity. Wastelands other than salt-affected and sandy areas should be restored to their primary production potential consistent with their post-reclamation capability. A major portion of such areas, as mentioned previously, may be used for plantation to provide vegetative cover. Chromusterts and Pellusterts need proper soil conservation measures based on detailed studies.

CONCLUSIONS

Study of landforms and soils of Krishna Godavari delta using remote sensing techniques revealed that the synoptic view

favoured by the Landsat imagery facilitated separation of three distinct eco- systems viz. Sea, coast and delta.

Multi-date imagery and topographical maps confirm that the delta is advancing and extending over the land system into the shallow seas. Wet lands and salinity are associated features, the mapping of which provides a sound basis for evolving the reclamation strategy to ward off the soil problems and for conversion of these areas into productive lands.

Temporal studies lead to prediction of migration and growth of spits in the delta front and to identification of weed flora in deltaic low lands.

Inland manifestation of salinity became obscure owing to high ground water table at places due to inundation, warranting development of different image interpretation keys for coastal salt lands.

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