



## Coastal zones in integrated river basin management in the West Coast of India: Delineation, boundary issues and implications



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### ABSTRACT

The management of the coastal region, its resources and stakeholder rights are treated in isolation from the associated river basins in most of the countries across the world. Incorporating the coastal stretch as an integral part of the basin becomes necessary due to the reciprocal relationships that exist between the coastal 'tail-end' ecosystems and upstream stretches. The present study addresses the challenges involved in integrating the coastal zones into the Integrated River Basin Management (IRBM) framework, especially in developing countries like India. As a part of this study, the river basins and their coastal watersheds in the west coast of India, a highly bio-diverse and densely populated region, is delineated using multiple high resolution datasets. A case study of one of the western coastal tracts is also attempted to identify the boundaries that have to be considered in the coastal zones for basin delineation. The ambiguities in the coastal drainage and floodplain boundaries due to the numerous cross-linkages that exist with the neighbouring estuaries, the multitude of small independent coastal catchments and asymmetries between surface and groundwater boundaries present difficulties in undertaking a strict hydrological delineation in the study region. Apart from these natural boundaries, various administrative/political units, coastal management frameworks, resource dependencies and livelihoods present additional boundary concerns for sustainable coastal management within IRBM. Taking these multiple boundaries of the coastal zone into account within the river basin regime becomes essential for resource sharing and legitimate interventions in upstream basin decisions that jeopardise the coastal ecosystem and livelihoods.

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### 1. Introduction

Coastal regions across the world are subjected to numerous and unrelenting threats both natural and anthropogenic which are projected to intensify in the near future (Nicholls et al., 2007). The link between the sea and the land is kept alive by the river systems that drain into these coastal reaches bringing in nutrients, silt and sediments from the mountain catchments and maintaining the delicate balance of the estuarine ecosystems and aquifers through fresh water flows. The era of intense development of these river basins centred on expansion of irrigation facilities and water sharing between the upper riparian catchments typically excluded the coastal regions, ultimately resulting in reduced river flows, concentrated pollution loads, accelerated erosion and highly

salinised water sources of the coasts. The coast as an integral element and tail-end socio-ecosystem of a river basin is not adequately incorporated even in the new era of source to sink integrated management of river basins oriented towards sustainable development. To a large extent, the ambiguities and difficulties in the delineation of the coastal zone and its boundaries is observed to contribute to the integration issues (Sas et al., 2010). The sustainable management of the coastal region, its resources and the stakeholder rights of its people is therefore either largely ignored or treated in isolation from its basin (Gowing et al., 2006).

The Agenda 21 of the United Nations Conference on Environment and Development (UNCED, 1992) had advised the countries with marine boundaries to organize Integrated Coastal Area and River Basin Management (ICARM). The recommendation influenced the European Water Framework Directive (WFD), the Land Ocean Interactions in the Coastal Zone (LOICZ) programme and United Nations Environment Programme (UNEP) into integrating the management of coasts with that of river basins in a 'ridge to reef' management effort (WFD, 2000; Salomons et al., 2005; UNEP,

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1999). But the experience of its implementation in several European river basins testify that coastal and estuarine regions continue to be marginal ecosystems on account of their smaller size in comparison to the larger catchment regions and the relatively powerless coastal communities that are easily ignored/out-manoeuvred by their more powerful upper basin stakeholders (Schernewski et al., 2005; Molle, 2006). Ambiguities and heterogeneities in delineation still persist in these regions despite clear definitions of coastal waters in relation to environmental legislation (Liquete et al., 2011). On the contrary, the coastal areas of the countries of the Global South (see UNDP, 2004 for details on Global South) are yet to be explicitly acknowledged as integral parts of river basin based planning efforts.

The coastal zones of the Global South, a highly populated and resource rich region, is composed of multiple boundaries that include those of maritime, terrestrial and riverine systems (Masalu, 2000). These boundaries may range across international to the regional/local and is affected by environmental, social, legal and economic realities of resource use of a region (Jarvis, 2006). Because of these complexities in interactions and the transition from land to the sea, the concept and boundaries of the coastal zone are very vaguely defined (Cendrero, 1989). Therefore delineation and definition of the geographic extent of coastal areas for sustainable management and stakeholder engagement continues to be a challenge despite the various coastal zone management frameworks of the past two decades that include Integrated Coastal and Ocean Management (ICOM), Integrated Coastal Management (ICM) and Integrated Coastal Zone Management (ICZM) (Boudreau et al., 2013). It is recognized globally that the delimitation of the coastal tracts is a high priority activity in any integrated management activity that often requires consideration of multiple scales both functional and political and the related problems of fit (Guerrin et al., 2014; Lamacchia et al., 2002; Sreeja et al., 2012). It is further pointed out that boundary assignments in the coastal regions are a mixture of socio-political, ecological and jurisdictional considerations (Balaguer et al., 2008). It is also argued that sometimes coastal boundaries are deliberately left fuzzy thus clouding coastal zone delineation (Mee, 2012). A successful and sustainable management of the coastal regions would require an integration of multiple boundary considerations in delineation (Cantasano and Pellicone, 2014).

In India, the Coastal Regulation Zone (CRZ) notification of 1991 had signalled a crucial turning point in the management of coastal resources (Panigrahi and Mohanty, 2012). These regulations had then gone through a long history of contentions, power wrangling for concessions, numerous modifications and were finally amended as the CRZ notification 2011 (Gol, 2011). During the course of these 20 years, the threats faced by the coastal and estuarine belt have loomed further, especially in the aftermath of the 2004 tsunami, the climate change threats of sea level rises and the continued development of the river basins without coastal considerations. The scope of the management regimes established through CRZ is also found to be increasingly inadequate since social and ecological changes in the coasts operate at much wider temporal and spatial scales. In India, ICZM is officially recognised as the means of coastal zone regulation in addition to the implicit assumption that coastal regions are also part of river basin management units (Panigrahi and Mohanty, 2012). But explicit delineation of these coastal regions as part of river basin units has not been attempted so far. At present, boundaries of the coastal zones in the country are defined in different ways depending on the focus of interest and availability of data (SAC, 2012). There is an urgent call for dealing with these mismatching scales through a better understanding of the various boundaries that operate in the coast as a natural resource management (NRM) region especially in the context of nascent

environmental governance regimes such as the river basin.

In this context, the present paper explores the boundary issues in the inclusion of the coastal regions of the west coast of peninsular India within the Integrated River Basin Management (IRBM) framework. The densely populated west coast of India is a biologically rich tropical tract with swift draining rivers from the western Ghat mountains forming complex coastal drainages before meeting the Arabian Sea. The rapidly changing livelihoods and resource use patterns, exhaustive development of its water resources and increasing conflicts over resources have heightened the need for sustainable resource management in the region. Many of the coastal states that constitute the west coast are in the process of forming river basin organisations and streamlining water resources development and management along river basin units. Hence understanding the coast as part of river basins has become crucial in the region. The specific objectives of the study include; i) the delineation of the coastal watersheds in the west coast of India to understand the river basin affiliation of the coastal stretches, ii) identification of various boundaries in coastal resource management and iii) assessing the relevance of these boundaries vis-à-vis river basin governance. Such an effort would contribute towards a better understanding of the coast as a socio-ecological space that is linked to its river basins. The coastal basin delineation undertaken here is a first of its kind effort in the west coast and is a prerequisite in the NRM and governance of these highly populous and bio-diverse tracts.

## 2. Materials and methods

There is a dearth of baseline data on the hundreds of short west flowing humid tropical rivers from the Western Ghat mountains of India which are considered to be amongst the few of the World's richest biodiversity hotspots (Myers et al., 2000). All river basin and watershed delineations attempted in India spearheaded by the Ministry of Water Resources as well as the technical bodies of Central Water Commission and Central Ground Water Board have always clubbed together the west-flowing rivers of Western Ghats as 'drainage flowing into the Arabian Sea' (CWC, 1989, 1997) or more recently as 'West flowing river basins south of Tapi basin' (India-WRIS, 2012) (for a detailed discussion on river basin classification in India see Pareta and Pareta, 2014). The early delineations of the world's major basins using 30 arc-seconds GTOPO30 global digital elevation model (DEM) (WRI, 2003) also completely ignored the peninsular river basins of India including the west coast basins. The more recent high resolution world watershed delineation called HydroSHEDS undertaken by the United States Geological Survey (USGS) using 3 arc-seconds resolution elevation data of the Shuttle Radar Topography Mission (SRTM) do provide a delineation of the west coast basins (Lehner et al., 2008), though it is unable to capture the coastal basin boundaries due to elevation uncertainties in the DEM in the coastal reaches. Hence all the available delineations of the west coast river basins are found to be unreliable and inadequate especially with regard to the coastal extent.

The river basin boundary and drainage characteristics of the west flowing rivers of the Western Ghats are derived as part of the present study in HEC Geo HMS module in ArcMap 10.2 software using the USGS SRTM DEM (3 arc-seconds resolution) data, processed by the International Centre for Tropical Agriculture (CIAT) (Jarvis et al., 2008). The DEM is corrected to fill the dips or data gaps by fill sink option. Flow direction and flow accumulation maps are derived from this fill sink map subsequently. The number of cells to initiate a stream is defined by specifying the maximum threshold (1000) for delineating drainages in the flow accumulation map. The sub-watersheds for each delineated stream are extracted depending upon the threshold. The sub-basins derived from SRTM are

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