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Invasion of *Prosopis Juliflora*: Still a Valuable Species in Arid and Coastal Areas of Tamil Nadu, India

SAMPATH KUMAR S[1] AND T S VISWANATHAN[2]

[1]*Department of Civil Engineering, Velammal Engineering College, Surapet, Chennai 600 066, Tamil Nadu, India*

[2]*School of Civil and Chemical Engineering, VIT University, Vellore, India*

Email: *sampatvec@gmail.com, visu_er@yahoo.com*

Abstract: *Prosopis Juliflora* plays a leading role in preventing erosion caused, mainly due to sea water in coastal areas and afforestation, in arid and semi-arid lands. Its capability of growing on saline areas and in arid and semi-arid conditions qualifies them suitable for this purpose. This species fits well into the agroforestry system for controlling desertification, soil erosion, sand dunes, improve fertiliser status, provide fuel energy sources, used in construction timber and furniture wood. It also provide nutritional supplement to humans and promote honey production. This plant can withstand high temperature, less water and high saline land. In India, *Prosopis Juliflora* is widely seen across in Gujarat, Rajasthan, Haryana and Tamilnadu.

Recently in Tamilnadu, there were lot of public protestation due to which the recent court orders issued a complete eradication of these species. This has now become a growing concern on this tree, which has invaded and become an obnoxious weed as this species had earlier proved a blessing for the dwellers of degraded wasteland and barren coastal areas which was prone for desertification, sand erosion and tsunami threat. The speciality of these species roots can go nearly up to 175 ft(53.5 mts) and access to water ways and deplete the ground water level. Hence, there is a need for a holistic study, to carry out with the help of spatial management system software such as Geographic Information System(GIS) and Remote Sensing techniques for studying the cause of ground water depletion in arid and semi-arid regions of Tamilnadu and sea water intrusion in coastal regions of Tamilnadu. Based on this, a methodology is formulated to identify the species even in more detailed way, to study the cause of sea water intrusion especially in these areas, due to these species.

Keywords: *prosopis juliflora, sea water intrusion, lagoon*

1. Introduction

Prosopis Juliflora is a thorny shrub with a height of 3 to 5 m or tree growing up to 15 m of height. It has a thick rough grey-green bark that becomes scalier with age. The plants are often multi-stemmed and furnished with abundant large and very sharp thorns measuring up to 5 cm. The tree is deeply rooted. The stems are shaped in a "mild zigzag" way with one or two stout thorns at each turn of the stem. (CABI, 2011)

Prosopis Juliflora can be a very aggressive invader and replaces native vegetation and takes over rangelands. Negative effects include complete loss of pasture and rangelands for both domestic and wild ruminants, losses due to access to water and the destruction of fishing nets by the thorns, and illness and death of livestock due to eating *Prosopis Juliflora* pods and being pierced by the sharp and stout thorns. Other impacts are loss of cropland, the costs of repairing tyres punctured or destroyed by thorns, and doctor's bills for treating thorn wounds. Dense stands of *Prosopis Juliflora* can block irrigation channels, obstruct roads and block smaller trails completely affecting access to pasture, croplands, water sources and fishing areas. Prosopis species are salt and drought tolerant with deep roots which tolerate dry as well as waterlogged soils. Seed production is prolific. Trees rapidly form dense thorny thickets that reduce biodiversity. Invaded grasslands are transformed to woodland and forests. Loss of grass cover under canopies may also promote soil erosion. It has massive impacts upon water resources. The tree re-sprouts easily after damage (Weber, 2003).

The '*Prosopis Juliflora* debate' has become an important topic of discussion, among different administrative departments and researchers in Tamilnadu during recent months. This is primarily due to aggressive spread of Prosopis Juliflora in arid and semi-arid regions in several districts of Tamilnadu. Invasion of grasslands, riverine forests and nature reserves has alarmed ecologists and farmers. Invasion of irrigation channels and arable land has affected the agricultural community, while pastoralists have seen the dwindling of their pasturelands. These groups have put pressure on the government through petitions and the court has directed for actions. The Tamilnadu government has forced to stop further planting of *Prosopis Juliflora* and begin eradication programmes, most notably in many parts of Tamilnadu. However, there are also many people who hold the view that Prosopis is a valuable resource in their dry lands, which means, it will affect the livelihood and that in any case eradication is a virtual impossibility, arguing that there is a need to control the species through careful exploitation.

But crop farmers from Chemonke village, Kenya, have had to seek alternative settlement elsewhere because they have lost their land to *Prosopis Juliflora* invasions, often resulting in conflict with established communities, (Mwangi and Swallow, 2005). Surveys of local communities around Lake Baringo revealed that 85-90% of respondents to a questionnaire favoured complete eradication of invasive Prosopis species (Mwangi and Swallow, 2004). In another study Maundu et al. (2009) found that 64, 79, and 67% of respondents interviewed in the Garissa, Loiyangalani, and Baringo areas of Kenya, respectively, said that life would be better without Prosopis. Over 90% of livestock owners in eastern Sudan regard invasive *Prosopis Juliflora* as a liability and pastoralists in Ethiopia refer to Prosopis as the "Devil's Tree".

Invading *Prosopis Juliflora* tends to form dense, impenetrable thickets, associated with unfavourable impacts on human economic activities. Millions of hectares of 22 rangelands have already been invaded, and the process is still occurring in South Africa, Australia and coastal Asia (Zeila et al., 2004). It is one of the three top priority invasive species in Ethiopia and has been declared a noxious weed. Sudan has passed a law to eradicate it (Sudan Update, 1997).

In the coastal areas to prevent erosion there were a number of important points were considered. Drifting sand was driven by new sand constantly blowing off the beaches. This could only be stopped by building and revegetating new fore-dunes. Vegetation needed to be resistant to seasonal drought, salt laden winds; wind carried sand abrasion, and high surface temperatures. Nutrient status of the freshly deposited sand was very low or none-existent. Work needed to start at the beach front or it was quickly overwhelmed by new sand deposits.

Low fertility of the site is assisted by planting the *Prosopis Juliflora* which is tolerant of salt and wind and also has a deep rooting habit. Trees planted into this thicket in turn are well sheltered while establishing and also benefit from the natural nitrogen in the system. Also these plants along with *Casuarinas* plantation have protected several hamlets in and around coastal region of Pulicat during 2005 Tsunami. As these species roots go nearly up to 175 ft (53.5 mts), this provides a natural shield of protection in coastal areas. But as the root goes deeper, it access fresh water ways and deplete the ground water level and causes imbalance in seawater and groundwater table along the coastal region. Hence, there is an immediate need to carry out a GIS and Remote Sensing based study on the cause of sea water intrusion.

2. Study Area

Pulicat Lake boundary limits range between 13.26° to 13.66° N and 80.03° to 80.25°E, is a coastal lagoon on the east coast of India, extending between Andra Pradesh and Tamil Nadu. A well-developed spit is observed at the mouth of the Pulicat Lake.

Figure 1: *Suvery of India map of Pulicat Lake*

Figure 1 shows the Pulicat lagoon which is the second largest lagoon in India. In Figure 2, the ruined Dutch Geldria Fort shown in green square patch is fully infested with *Prosopis Juliflora* vegetation. This area was identified as a part of study for Sea Water Intrusion.

Figure 2: *Dutch Geldria Fort near Pulicat Lake*

The coastal dunes in Pulicat region are stabilized and covered by *Casurina*, *Coconut*, *Palmyra* and *Prosopis Juliflora.* (SAC, 2012).

3. Sea Water Intrusion

Natural movement of fresh water towards the sea prevents salt water from entering freshwater coastal aquifers (Barlow, 2003). The Sea water intrusion is contaminating some of the most important aquifer systems in economic terms. As the sea water moving preferentially through high permeability layers in the ground over 60% of coastal aquifers are contaminated by seawater intrusions in Indian context (Figure 3).

3.1 Causes of Seawater Intrusion

- Uneven Precipitation
- Limited Recharge of Surface-water or fresh ground water is sometimes partially replaced by seawater which is drawn into the aquifer
- Artificial over pumping
- Lithology
- Geological Structure
- Utilisation of limited water resources with the local condition
- Deep Rooted Vegetation

One of the major concerns most commonly encountered in coastal areas are due to induced flow of saltwater due to over pumping of ground water, which is known as salt water intrusion. This study emphasis on the cause of *Prosopis Juliflora* vegetation, due to its deep rooted behaviour it contributes to saltwater intrusion. The key to control this problem is to maintain the proper balance between freshwater and saltwater, also selections of appropriate alternate vegetation need to be proposed instead of *Prosopis Juliflora*. Delineation of saltwater and freshwater interface and close monitoring of the position of variation of the interface by both direct hydraulic and indirect geophysical field surveys is needed to be studied. Water usage forecasting methods through computer modelling and analytical solutions were used to explain the fundamental concepts of the physical problem of saltwater intrusion. An analytical solution can often provide a relatively simple but clear concept of the problem. Following section explains the most fundamental analytical solution used for saltwater intrusion problem.

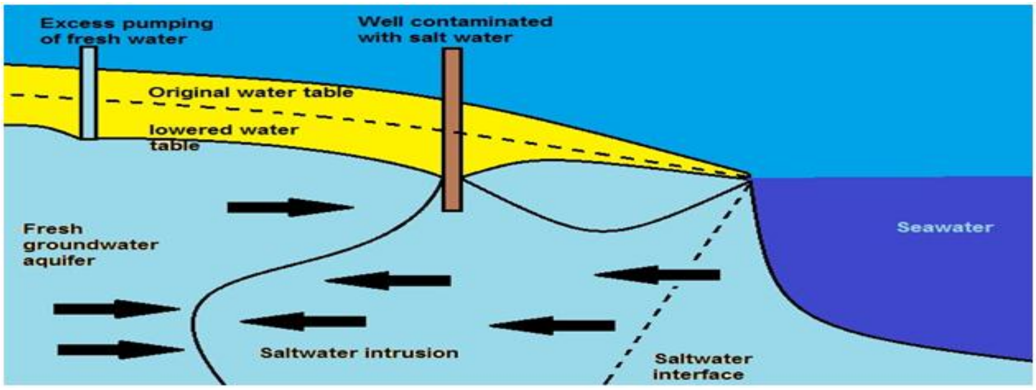

Figure 3: *Sea water Intrusion and saltwater interface*

The first physical formulations of saltwater intrusion using analytical solutions were made by W. Badon-Ghijben (1888, 1889) and A. Herzberg (1901) observation recorded by Verrjuit, Arnold (1968)., thus called the Ghyben-Herzberg relation. They derived analytical solutions to approximate the intrusion behaviour, which are based on a number of assumptions that do not hold in all field cases. The Ghyben-Herzberg relation states that under hydrostatic conditions, the weight of a unit column of freshwater extending from the water table to the interface is balanced by a unit column of saltwater extending from sea level to the same depth as the point on the interface (Figure 4).

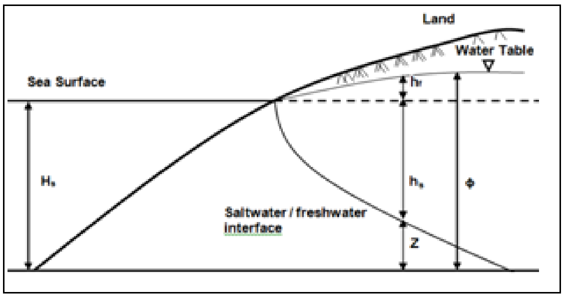

Figure 4: *Ghyben-Herzberg relation for the saltwater-freshwater interface*

This could be mathematically expressed as:

$$h_f = \frac{\rho_s - \rho_f}{\rho_f} h_s$$

Where h_f is the elevation difference between the phreatic surface (ground water table) and the sea level; h_s is the elevation difference between the sea level and the sea water-freshwater interface at a given point. ρ_s and ρ_f are the density of the sea water and the fresh water, respectively. The Gyhben-Herzberg Relation can also be expressed by the elevation of the interface from the bottom of the aquifer Z by

$$Z = \frac{1}{\rho_s - \rho_f}(\rho_s H_s - \rho_f \emptyset)$$

Where the total head $\emptyset$ is the elevation of the groundwater table, Hs is the thickness of seawater from the impermeable aquiclude.

$$\emptyset = h_f + H_s$$

The total head $\emptyset$ can also be written as

$$\emptyset = H_s + h_f = Z + h_s + h_f$$

This analysis assumes hydrostatic conditions in a homogenous, unconfined coastal aquifer. How deep the seawater can intrude towards the land depends on the gradient ascending from the sea level. If the saltwater density is 1.025 g/cm^3, according to the Ghyben-Herzberg relation, if the water table in an unconfined coastal aquifer is lowered by 1 m, the saltwater interface will rise about 40m. Apparently, this can result in a tremendous loss of freshwater resources. This value will vary from place to place, depending up the density contrast between the seawater and the freshwater.

In Practice, the Ghyben-Herzberg relation and modified Ghyben-Herzberg(which uses the observed piezometric head in saltwater zone) method can be used for preliminary estimate of the location of saltwater-freshwater interface (Lanbo Liu 1998).

Although sea water intrusion into coastal aquifers is a long-studied problem (Ghyben 1888; Herzberg 1901), the relatively recent development of advanced numerical models has enabled in-depth three-dimensional modelling of fresh water-sea water interactions at specific sites (Yeh and Bray 2006; Bray et al. 2007; Kumar et al. 2007). FEFLOW is one such numerical modeling software system capable of accounting for density-dependent solute transport (Diersch 2006; Trefrey and Muffels 2007) and thus, appropriate for simulating sea water intrusion in coastal aquifers caused by natural and anthropogenic processes.

Large coastal cities have been faced with the problem of saltwater intrusion for decades and this problem has been researched in great depth. Some US cities have attempted to maintain groundwater levels by ponding surface runoff or river water to slowly recharge the groundwater table. Other methods include hiring consultants to perform extensive research and mapping of local aquifers to determine groundwater flow followed by setting up barrier wells near the shore to pump out salt water and to help recharge a freshwater gradient toward the sea or by placing a series of closely spaced injection wells near the coast and injecting them with high quality freshwater creating a hydraulic pressure ridge. To summarize, recharge wells, injection wells, recharge basins, and barrier wells have been effective in maintaining the proper equilibrium between groundwater recharge and pumping for large city water supplies around the world. These methods would cost a city anywhere from tens of thousands to hundreds of thousands of dollars and are therefore not solutions for private wells owners. (Brunswick 2015)

Generally, saltwater intrusion into coastal aquifers is caused by two mechanisms:

- Lateral encroachment from the ocean due to excessive water withdrawals from coastal aquifers, or
- Upward movement from deeper saline zones due to upconing near coastal discharge/pumping wells.

In Late 1960's, efforts rose toward drilling for chemical analysis of groundwater samples and the determination of flow patterns based on piezometric levels. Geophysical methods of investigation were introduced later, and were found to provide more information faster than the drilling techniques. Subsequently, geophysical methods became more important for saltwater intrusion monitoring. Today, there are numerous methods available including: well logging, chemical analysis of groundwater samples, research into the interaction between aquifer matrix and groundwater, and most common, chloride concentration profiling, and vertical conductivity and temperature profiling.

4. Delineation and Estimation of Saltwater-Freshwater Interface using GIS and Remote Sensing

GIS and Remote Sensing techniques were to be used in the study area around the Pulicat Lake, which is the second largest brackish – water lake or lagoon in India, after Chilika Lake. It straddles the border of Andhra Pradesh and Tamil Nadu states on the Coromandal Coast in South India, with more than 95% of the lake within the border of Andhra Pradesh and less than 5% within Tamil Nadu. Patches of residual, dry, evergreen forest and large areas of littoral scrub in woodlands in fishing villages bordering the lagoon are seen. Invasive phytoplankton species of *Prosopis Juliflora*, in the plains on the periphery of the lake have been recorded.

Figure 5: *FCC IRS LISS III Image of Study Area*

The lagoon's boundary limits range between 13.26° to 13.66° N and 80.03° to 80.25°E, with a dried part of the lagoon extending up to 14.0°N.; with about 84% of the lagoon in Andhra Pradesh and 16% in Tamil Nadu. The lagoon is aligned parallel to the coast line with its western and eastern parts covered with sand ridges. Currently, *Prosopis Juliflora* is rapidly invading in Pulicat and the traditional pastoral with other good vegetation area has encroached hundreds of kilometers away from the earlier.

With the use of cloud free Indian remote sensing satellite IRS – LISS III (Figure 5) and ID data which has spatial resolution of 23.5 m. a study need to be conducted with the help of GIS Software. The FCC (False Colour Composite) from satellite data was prepared with the use of Intergraph Geomedia Desktop 2014 a GIS and Image Processing Software. To estimate the saltwater-freshwater interface GCP's containing piezometric head data were collected. The procedure for estimating is as follows:

a) Collect piezometric head data and use statistic kriging to plot the contour map
b) Contour maps showing the elevation of saltwater/freshwater interface can be obtained by the Ghyben-Herzberg relation:
c) Collect Geological information that marks the aquifer bottom boundary
d) The intersection of the interface and the aquifer bottom can be delineated

Figure 6, shows the overall methodology using GIS and Remote Sensing to delineate the saltwater interface and indentify the major cause of intrusion.

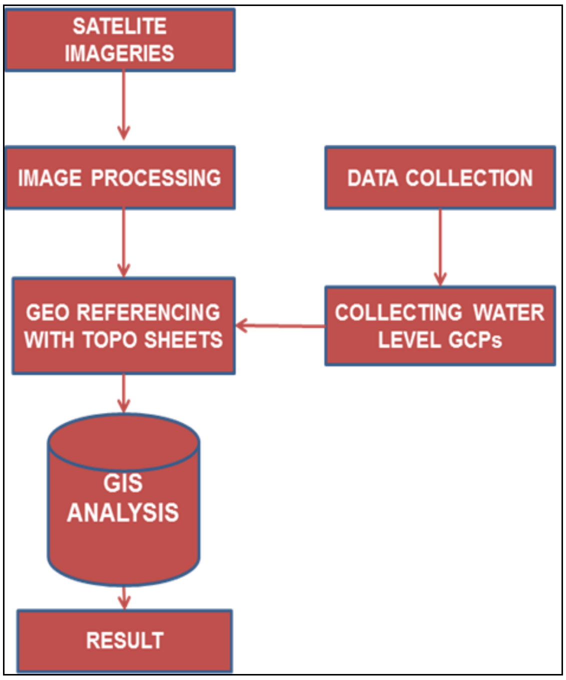

Figure 6: *Flowchart of GIS and Remote Sensing for assessing Saltwater Intrusion*

5. Result and Discussion

On the basis of collected field data GCP having the fresh and salt water level data, the differences need to be recorded as tonal/colour or density variations on the imagery to assess after the interface delineation made. Further, by using both direct and indirect methods, we can detect the existence of salt water in aquifer where saline contamination is suspected. The Supervised classification methods were planned at a 1:50,000 scale for analysis. The result has shown the expansion of *Prosopis Juliflora* in Pulicat area by using LISS III IRS lC and ID data of post monsoon years since 2012.

6. Conclusions

Prosopis Juliflora invasion although useful, it is a threat to Pulicat livelihood mainly due to sea water intrusion. Action needed to be taken to reduce the negative impacts of the same. Although majority of people in that area and all over many parts of Tamilnadu prefers complete eradication over control, a swift action and a holistic view on that need to be taken care for a balanced approach. It is better to understand the need and the spreading patterns of *Prosopis Juliflora*, identifying conditions where that favours its spread is essential verses complete eradication. In places for complete eradication alternate vegetation need to be suggested for preventing soil erosion and afforestation. Further research need to be carried out on *Prosopis Juliflora* and its interference in sea water intrusion which is very vital study in today scenario.

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