Simulation of Impact of Prosopis Juliflora on River Flooding using HEC-RAS

M. Krishnaveni[#1], Arunya KG[*2]

[#]*Centre for Water Resources, Anna University*

[1]mkveni@annauniv.edu

[2]18241197155@annauniv.edu

Abstract — **River is defined as a natural stream of water of fairly large size flowing in a definite course or series of diverging and converging channels. The functions of the river are to carry water from the basin to the ocean. Through this process it recharges the ground water, washes away the unwanted nutrients, sediment transportation, mineral deposition, accumulation of water in storage structures, etc. The environmental flow of the semi-arid region rivers is affected mainly by the issues such as erratic rainfall which leads to floods and droughts, improper maintenance of the river system, absence of river banks, loss of ecosystem, etc. The main objective of this study is to do Rapid Rural Appraisal (RRA) to find out the issues in the functions of the river. During the filed study many issues like occupancy of Prosopis Juliflora, sand mining, detachment of streams, improper maintenance, etc was identified through which the river has lost many functions. Among all the issues *Juliflora* has been founded as one of the basic issues which occupies the river bed. Prosopis Juliflora is one of the most economically and ecologically crucial tree species in arid and semi-arid zones of the world. [12]. It creates many hydrological impacts like modified flow regime, altered species composition, modified channel form, increased bank erosion, loss of species habitat, modified nutrient content, decrease in the velocity of flow, changes in river geometry which totally leads to the collapse of river system. So, an attempt is made to do flood modelling using HEC RAS for finding the flow of water with and without the presence of *Juliflora.* Also, policy options for removal and maintenance of *Juliflora* along the river stretch is recommended. Finally, for other existing issues in the river system, sustainable restoration techniques were suggested in order to restore the river.**

Keywords — **Rapid Rural Appraisal, Juliflora, Flood, Policy options, Restoration.**

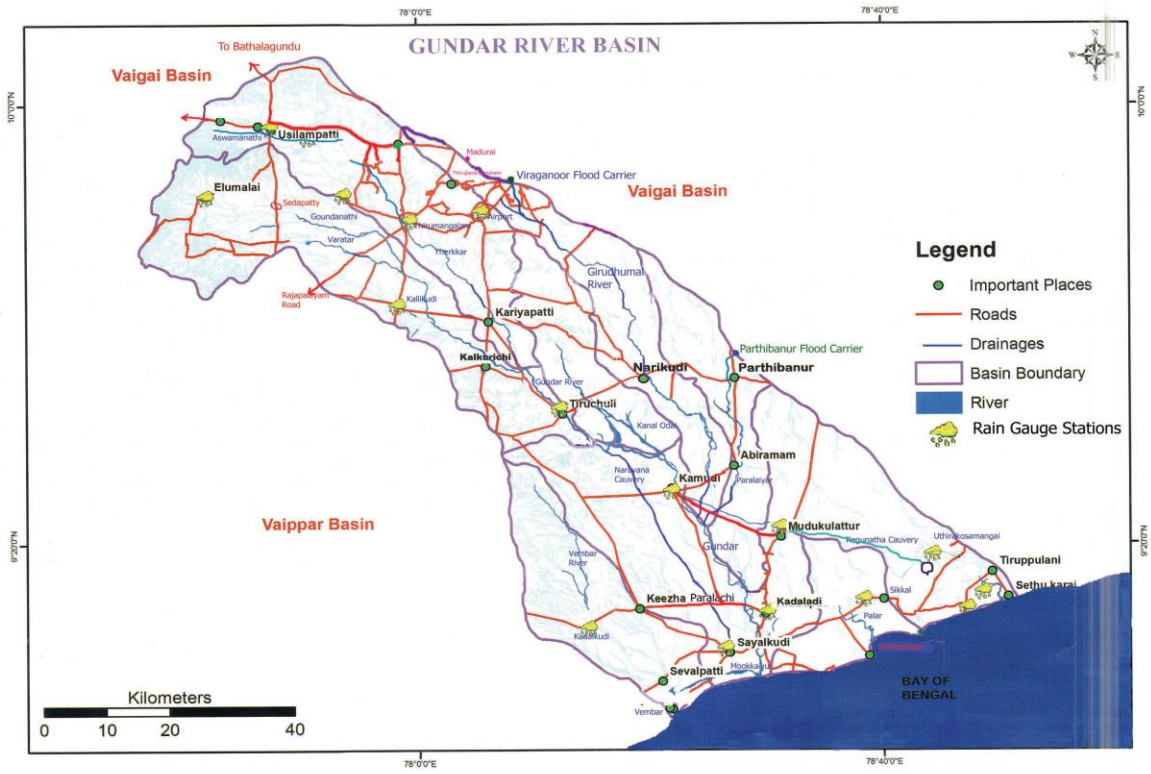
I. INTRODUCTION

The semi-arid region rivers had lost many of its functions due to the climatic variations, and anthropogenic activities which leads to environmental degradation of river and estuarine ecosystems. But not all the rivers are damaged likely, each one of the rivers was damaged in its own specific features. For Effective restoration of a particular river, the issues need to be identified so that the exact management could be done. Therefore, this paper focuses on finding out the issues of a semi-arid river by RRA. RRA group contains Public Works Department (PWD) engineers, officers, academicians and farmers. Each and every problem of the river was identified by visiting every major stretch, diversion and control structures along the river course. During the analysis one of the main requirements found for restoration of semi-arid river basin is the removal of occupancy of Prosopis juliflora, which is a major threat to the flow of river. Prosopis juliflora, a Thorny Shrub, grows immensely and spreads mainly due to its inbuilt mechanism to overcome adverse conditions like drought and salt [12]. With deep penetrating roots, it can draw water from deeper layers [1], [4]. Prosopis juliflora can be a very aggressive invader and replaces native vegetation and takes over range-lands. It has been established as noxious and as an invasive weed in Africa, Asia, Australia and elsewhere [12], [5]. Though the species has played a role in changing land use and the livelihood security of huge populations of the world, due to poor management practices, it has colonized many important ecosystems, creating a negative pressure on biodiversity [17]. It is hard and expensive to remove as the plant can regenerate from the roots. The tree reproduces by way of seeds, not

vegetative. Seeds are spread by cattle and other animals that consume the seed pods and spread the seeds in their droppings. A mature plant can produce hundreds and thousands of seeds. Seeds remain viable for up to 10 years.

Fig. 1 Index map of Gundar River Basin

II. STUDY AREA



Source: PWD, Kamudi

Fig. 2 Gundar River

A. Gundar River Basin

Gundar is one of the major river basins in Tamil Nadu with a drainage area of 5690 sq.km. It is located between 9°05' – 10°05' N and 77°35' - 78°35' E. It is situated between Vaigai river basin in north and Vaipar river basin in south. The basin covers part of Madurai, Sivaganga, Virudhunagar, Ramanathapuram and Thoothukudi districts. Length of the Gundar river is 150 km. The base map of the Gundar basin is created using GIS. The river Gundar originates near Chathuragiri hills with tributaries namely Kamandalanadhi, Goundanadhi and Varattar and flows towards South-east direction. The rivers Therkar and Goundanadhi join near Pudupatti village from which the main river Gundar starts. The Kanalodai joins Gundar near Mandalamanickam village. The other main tributaries namely, Gridamal and Paralaiyar joins the river Gundar near Keelavalasai village. The river Malattar originates near Reddiyapatti village and confluences in the Gulf of Mannar. There are 18 non-recording rain gauges in the river basin. Climatology, it lies in mixed weather region. Generally, floods occur during north-east monsoon period when there is heavy rainfall coupled with cyclonic storms.

III. ENVIRONMENTAL ISSUES OF RIVER SYSTEM

Overall status of the river was understood by analyzing all the issues. In every river system there will be positive and negative impacts due to the climatic, physical, ecological and social issues. The positives need to be strengthened if needed, and the negatives need to be cut backed up to the lowest level of causing damages. Here the positives are the existing physical flood control structures. There were enough structures for flood control but with some structural damages due to lack of maintenance. Then the negatives are plugged smaller streams which reduces the flow into the river stretch, occupancy of Prosopis juliflora, sand mining, consequent floods and droughts, modified elevation of river bed and absence of river banks. Identified issues are shown in Figure.3

The issues are mainly due to the climatic system, human activities or the anthropogenic activities and the societal system. Changes in the climatic system is the basic issue which causes variations in seasonal rainfall which creates consecutive floods and droughts. Hence the environmental flow got affected and it also affects the ecosystem. The issues which are created by the human activities are the absence of river banks and improper maintenance which leads to ungraded river bed and sand mining. Due to this the flow got obstructed which paves way for intrusion of invasive species like juliflora which spreads all over the river bed. Hence the flow got reduced and the existing flood control structures were become un noticed and the damages in the structures were happened. Now, the river had lost its livelihood. The river was considered useless by the people, which leads to the mindset change among the people by reducing the cultural heritage of the river.

Fig. 3 Identified issues along the river stretch

IV. FLOOD SIMULATION WITH AND WITHOUT JULIFLORA

One of the substantial issues in this basin is the occupancy of Prosopis Juliflora. It creates several hydrological damages like the reduction of flow, reduction in the velocity of flow, changes in water chemistry such as increase in nutrient, changes in geometry, flash floods, low flows and temporary removal of water. For maintaining, the occupancy of Juliflora need to be eradicated form the river stretches Therefore, to model the impacts of juliflora in the river bed an attempt was made to do flood modelling using HEC RAS.

Flood year was identified using the Rainfall analysis for which the rainfall data was collected from IMD. The flood year chosen for simulation is 2005. In this region the flood frequency is 10 years. For simulating the flood, using HEC RAS the data needed were the flood discharge which was collected from DMS Teynampet. The downstream stretch of Gundar river was taken which was completely occupied with Prosopis Juliflora. The Digital Elevation Model was downloaded from the earth explorer which was used as the base image. The DEM was processed and the cross sections were manually drawn. Then the flood peak discharge data was entered. the flood was simulated and processed for the criteria without the presence of juliflora. For this the roughness was given as

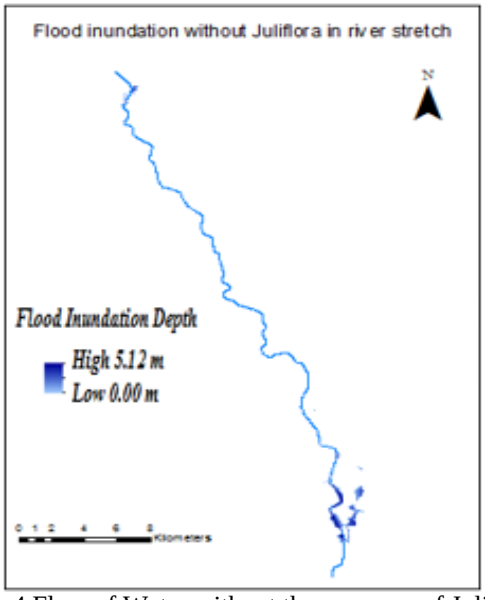


Fig. 4 Flow of Water without the presence of Juliflora in Arc GIS

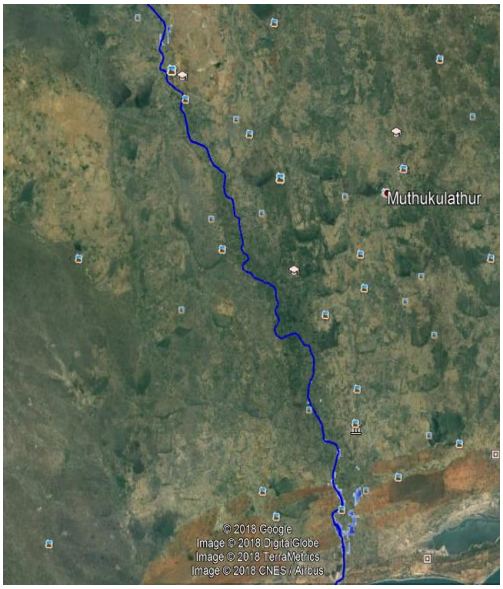


Fig. 5 Flow of Water without the presence of Juliflora in Google Earth

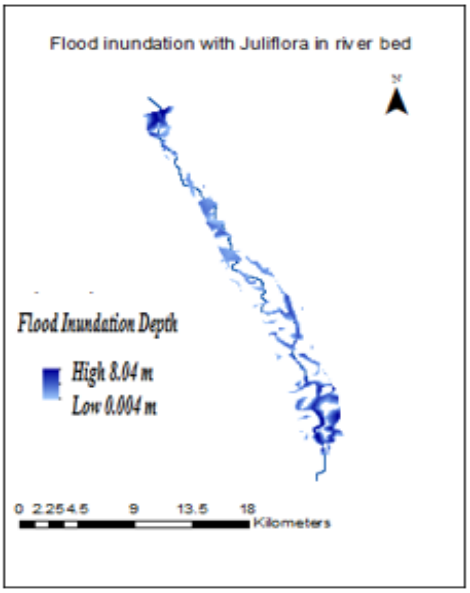


Fig 6 Flow of water with the presence of juliflora in ARC GIS

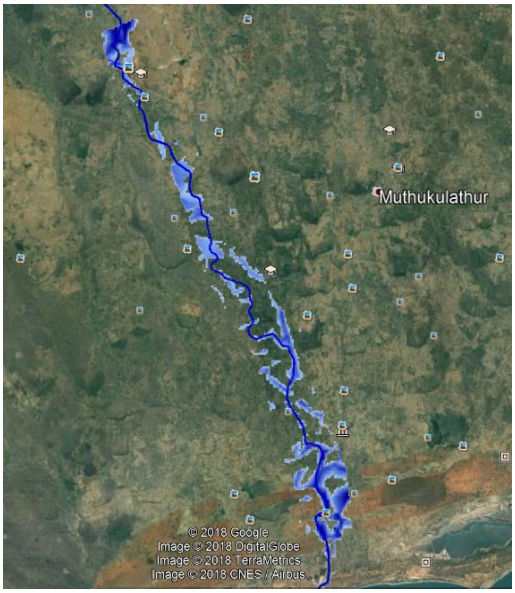


Fig 7 Flow of water with the presence of juliflora in Google Earth

0.02 as per natural channel roughness (Chow VT *et al., 1988)*. It shows that the maximum flood inundation depth is 5 meters. Most of the water flows exactly inside the river, only a meagre amount of water in the downstream got over flowed. Then flood was simulated, processed and visualized for the presence of Juliflora in the river bed. For this the roughness coefficient is given as 0.2 as referred from (Chow VT *et al., 1988)*. It shows the maximum flood inundation depth is 8 meters. Hence there is a 3 meters difference in the flow of water. It is now proved that juliflora in the river bed obstructs the flow and cause flooding, which leads to improper storage of water and it leads to the loss of river livelihood. Now it is validated that Juliflora obstructs the flow heavily which leads to flood, thereby inundating the nearby lands. So, the invasion of juliflora need to be eradicated.

V. POLICY OPTIONS FOR JULIFLORA ERADICATION

Prosopis Juliflora is a species which is spreading rapidly and widely, particularly in the areas of riverine, coastal, sub-coastal and residential. There is no clear policy and strategy to control and manage the invasive juliflora species at the National level. Nevertheless, to the plant biodiversity Prosopis invasion has been recognized as an emerging threat (John Livingstone *et al.,* 2014*)*. So, strategies and action plans need to be developed and set in place immediately. To increase the proper utilisation of Prosopis Juliflora the Ministry of Environment should strongly recommend efforts.

A. Policy Recommendations for Eradication of Prosopis Juliflora

- An institutional set up has to be created for organising and monitoring the eradication of Prosopis Juliflora.
- National policy guidelines and strategy should be developed, for the control and management of Prosopis Juliflora species with clearly defined roles and responsibilities at all levels. Also, for mobilization of stakeholders for implementation, a detailed guideline and techniques should be prepared (John Livingstone *et al.,* 2014).
- Prosopis Juliflora products should be promoted for commercialization, so that the plant can be used beneficially.
- The production and utilization of charcoal from Prosopis species should be promoted.
- Corporate Social responsibility should be incorporated for the eradication of juliflora.
- Further studies need to be conducted on the usefulness and nutritional content of Prosopis and for mapping its expansion.

VI. RIVER RESTORATION MEASURES

River restoration can be defined as ‘a structural and functional return to the pre-disturbance state’, in other words, ‘river restoration is the act of working with a degraded river or stream in order to return it to a pre-disturbed condition’. The goal is to establish self-sustaining stream functions and return an ecosystem to a former natural condition.

Issues related with the climate systems cannot be restored directly. It can only be achieved through gradual reduction in the factors which causes climate variability such as greenhouse emissions, promoting more carbon storages, developing and rehabilitating storage structures, planting more tress and changing the micro-climate through this.

Banks can be stabilized by raising bunds embankments should be created then above the bund’s trees need to be planted which makes the bund stabilized and also it enhances the ecosystem and habitats. By the trees which presents above the bunds the bunds can be saved from sand mining also. The smaller streams need to be identified with the previous maps. Then at places where it is possible to restore need to be marked and the streams should be regraded again. It can be done with the help of institutions through Corporate Social Responsibility. And many industries are willing to do this job.

Sand mining can be arrested if stringent policies are implemented and monitored properly. And if the river becomes lively by river restoration, the sand mining will abide automatically

The structural damages in existing structures can be repaired using the method called Routing and Sealing of Cracks. This is the method which can be done by filling and sealing the exposed face of the crack by enlarging

it along the crack with a suitable joint sealant. It is commonly and effectively used for water proofing, by sealing the cracks on the concrete surface at the place where water stands, or at the place where hydrostatic pressure is applied. It can also arrest other problems which causes the surface strains by means of moisture which passes through the concrete and reach the reinforcement. The materials of the sealants may consist of asphaltic materials, polymer mortars, epoxies, urethanes, silicones ad polysulfides. Due to the likelihood of cracking the cement grouts need to be avoided.

The social behavioural and psychological mind set of the people towards the significance of river can be enhanced if all the issues were rectified.

VII. CONCLUSION

River is one of the major systems which needs to maintain all the functions for its livelihood. River functions got affected due to the many issues like sand mining, consecutive floods and droughts, changes in the river geometry, absence of river banks loss of ecosystem, which was identified during the field study. From the issues identification it was found out that the river system is affected especially due to the presence of juliflora, which totally collapse the functions of the river. So, the impacts in the flow of river with and without the presence of juliflora was validated using flood simulation modelling and techniques, policy options were suggested for eradication of Prosopis Juliflora. Also, for sustainable restoration of river the restoration techniques were suggested for the other identified issues in the river system.

ACKNOWLEDGMENT

I wish to express sincere thanks to PWD department Madurai, Kamudi, DMS Teynampet and IMD for sharing their Valuable data and information for my work. I am glad to convey my gratitude to my family and friends for their continuous support throughout this work.

REFERENCES

[1] Canadell J, Jackson R, Ehleringer J, Mooney H, Sala O, et al. (1996) Maximum rooting depth of vegetation types at the global scale. Oecologia 108: 583–595.

[2] Chow VT, Maidment DR, Mays LW (1988) Applied hydrology. McGrawHill, New York.

[3] DubaleAdmasu (FARM-Africa), (2008) “Invasive Plants and Food Security: the case of Prosopis juliflora in the Afar region of Ethiopia”. David R. Godschalk, David J. Brow, (1985) “Mitigation Strategies and Integrated Emergency Management” Public Administration Review, Vol. 45, Special Issue: Emergency Management: A Challenge for Public Administration, pp. 64-71.

[4] Elfadl, M. A. 1997, Management of *Prosopis juliflora* for use in agroforestry systems in the Sudan, Tropical Silviculture Unit, University of Helsinki, 16

[5] Gallahar T, Merlin M (2010) Biology and impacts of Pacific Island invasive species. 6. *Prosopis pallida* and *Prosopis juliflora* (Algarroba, Mesquite, Kiawe) (Fabaceae). Pacific Science 64: 489–526.

[6] Groll M, (2017) “The passive river restoration approach as an efficient tool to improve the hydromorphological diversity of rivers – Case study from two river restoration projects in the German lower mountain range,” *Geomorphology*, vol. 293, pp. 69–83.

[7] John Livingstone, Kaise Abdi and AmsaleShibeshi, Somaliland, “The Management and Utilization of Prosopis Juliflora Policy Workshop”, 2014.

[8] Langhans S.D, J. Gessner, V. Hermoso, and C. Wolter, “Coupling systematic planning and expert judgement enhances the efficiency of river restoration,” *Sci. Total Environ.*, vol. 560–561, 2016, pp. 266–273.

[9] Ministry of Encironment and Forest, “Sustainable sand mining management guidelines”, Government of India 2016.

Palmer M.A, and J. D. Allan, “Restoring rivers,” *Issues Sci. Technol.*, vol. 22, no. 2, 2006, pp. 40–48.

[10] Palmer M.A, K. L. Hondula, and B. J. Koch, “Ecological Restoration of Streams and Rivers: Shifting Strategies and Shifting Goals,” *Annu. Rev. Ecol. Evol. Syst.*, vol. 45, no. 1, 2014, pp. 247–269.

[11] Pan B, Jianping Yuan, Xinhua Zhang, Zhaoyin Wang, Jinyou Lu, Wenjun Yang, Jiao Chen, Zhiwei Li, Na Zhao, Mengzhen Xu “A review of ecological restoration techniques in fluvial rivers,” *Int. J. Sediment Res.*, vol. 31, no. 2, 2016, pp. 110–119.

[12] Pasiecznik N, Felker P, Harris P, Harsh L, Cruz G, et al. (2001) The *Prosopis juliflora* – *Prosopis pallida* complex: A monograph. HDRA, Coventry, UK. 172 p.

[13] Sakthivadivel R., “Prosopis juliflora in the irrigation tanks of Tamil Nadu” Water Policy Research Highlight, IWMI TATA water policy program.2016.

[14] Schlatter K.J, M. R. Grabau, P. B. Shafroth, and F. Zamora-Arroyo, “Integrating active restoration with environmental flows to improve native riparian tree establishment in the Colorado River Delta,” *Ecol. Eng.*, vol. 106, 2017, pp. 661–674.

[15] Sunil Kumar, Anil Jaswal, Ashish Pandey, Nayan Sharma, “Literature Review of Dam Break Studies and Inundation Mapping Using Hydraulic Models and GIS” International Research Journal of Engineering and Technology (IRJET) Volume: 04, Issue: 05, May -2017, pp -55-61.

[16] Shanwad U. K., B. M. Chittapur, S. N. Honnalli, I. Shankergoud, Tegegnework Gebremedhin, "Management of Prosopis juliflora through Chemicals: A Case Study in India" Journal of Biology, Agriculture and Healthcare ISSN 2224-3208 (Paper) ISSN 2225-093X (Online) Vol.5, No.23, 2015, pp 30-38.
[17] Van Klinken R, Graham J, Flack L (2006) Population ecology of hybrid mesquite (*Prosopis* species) in western Australia: How does it differ from native range invasions and what are theimplications for impacts and management? Biological Invasion 8: 727–741.
[18] Zbigniew W. Kundzewicz, "Non-structural Flood Protection and Sustainability" Water International, Volume 27, Number 1, March 2002, pp 3-13.