International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 9 ǁ September 2022 ǁ PP. 359-366

A Case Study on Earthern Embankment Protection Techniques

Anju Mary Ealias[1,2]
[1] *Division of Civil Engineering, Cochin University College of Engineering, Kuttanad, CUSAT, Kerala, India*
[2] *Department of Civil Engineering, SCMS School of Engineering and Technology, Kerala, India*
Corresponding author: anjumaryealias@gmail.com

ABSTRACT
Kuttanad is one of the few places in the world where farming is carried out at below sea level. The main crop produced in Kuttanad is paddy. The method employed to avoid water ingress and to maintain soil fertility in the paddy fields involves construction of a bund which makes the soil suitable for cultivation. However, the recent floods in the state has shown us that such bunds are susceptible to damage from flood pressure and this badly affects the livelihood of farmers. This situation calls for a detailed study on bund protection systems currently used and rethinking of the design of the bunds. The study intends to focus on understanding the methods employed by farmers for the protection of their paddy fields below sea level in Kuttanad area of Kerala state with thrust on the issues faced by them due to frequent floods in the region. The heavy floods in the state in 2018 particularly devastated agriculture cultivation due to bund failures in Kuttanad and have prompted the authorities for rethinking upon the existing bund protection systems. This paper intends to highlight the issues with existing bunds using secondary data from newspapers, journals and government departments and provides a few case studies across the globe which may be suitably taken up by the authorities for implementation in Kuttanad.

KEYWORDS
Bund, Flood, low lying area, Paddy, Soil, Cultivation, Spillway

---

Date of Submission: 03-09-2022 Date of acceptance: 17-09-2022

I. INTRODUCTION

Kuttanad is a region spread in the Districts, Alappuzha, Kottayam and Pathanamthitta in the state of Kerala. Kuttanad is popularly known as the rice bowl of Kerala, owing to its vast paddy fields and is one of the few places in the world where farming is carried out at around 1.0 to 3.0 m below sea level. Kuttanad is a wetland formed by draining delta swamps in brackish water. This region is drained by a network of rivers, canals and man-made channels. Vembanad Lake is the major source of water for cultivation in Kuttanad.

The paddy fields in Kuttanad are wetlands, either natural low-lying land formations or man-made reclamations from the Vembanad Lake and are classified into three distinct zones viz., Karappadam, Kayal lands and Kari lands. Karappadam lands (about 33,000 ha) are areas of alluvial soils situated along waterways and constitute the lower reaches of the eastern and southern periphery. There are at a higher elevation than the kayal and kari soils. They are moderately acidic in reaction. Kayal lands (about 13,000 ha) constitute padashekharams reclaimed from the Vembanad Lake with elevations between 1.5 to 2.2 m below MSL. The soil strata padashekharam are neutral in reaction and contain vast deposits of fossils of lime shells beneath the topsoil. Kari lands (about 9,000 ha) have black peaty acidic soils and are located at or below MSL to the North (Vaikom), West (Thuravur) and South-West (Ambalapuzha, Thakazhi and Purakkad).

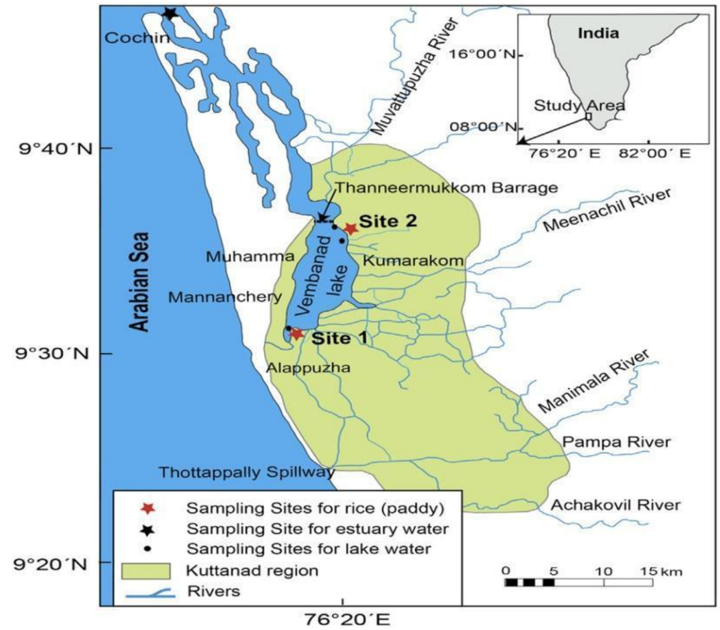

Figure 1. Site Map of Kuttanad [1]

The soil in this region is very soft, highly compressible and it has high organic content. This severely affects strength properties of the soil. The low shear strength and very high natural moisture content of Kuttanad clay made it poor foundation material, The main parameter which influences the soil strength are soil plasticity and moisture content.

Limited availability of potable water in Kuttanad is another main constraint for agriculture. Due to the low level of the region, sea water enters Kuttanad which significantly increases the salinity of water and making it unusable for cultivation. A common solution to enable cultivation in this scenario involves construction of a bund which retains the soil and water in the fields in good condition.

II. LITERATURE REVIEW

Kuttanad was one of the areas most affected by the flood in recent years. During the flood of June, July and August 2018 in Kerala, Kuttanad region was severely affected. Kerala state Planning board [2] in 2019, estimated that due to heavy rainfall and subsequent breaching of polder walls, more than 50,000 houses in Kuttanad were fully or partially drowned, Paddy crop cultivated in about 15,000 ha was destroyed and uprooted more than 10,000 coconut palms.For the development of Kuttanad region, a detailed plan was prepared by Travancore Government in 1950s with the objectives to stabilize the ‘puncha crop’ by regulating the entry of salt water into Vembanad lake and to facilitate a second crop of paddy during the monsoon months by draining out the rainwater from wetland plots into the lake and then to the sea. The plan also aimed to improve the transportation and communication systems within the region. As a solution to uncertainties present in Kuttanad region, a plan to construct a spillway at Thottappally to drain flood water from Pamba, Achankovil and Manimalarivers into the sea was envisaged. Also construction of a salt water barrage at Thanneermukkom to prevent intrusion of saltwater into the Vembanad lake from Kochi side and a road (AC road) cum canal connecting Alappuzha and Changanassery to improve communication and transportation as well as drain flood water from upper Kuttanad into Vembanad lake was planned. The construction of the Thottappally Spillway was completed in 1958. The first phase of the Thanneermukkam Bund was completed in 1965 and the second phase was completed in 1975. The third phase remained on the anvil. Work on the AC Road was completed by the 1990s.

The report [2] also highlighted the plan of the Government to construct permanent bunds around all the padasekharams. If the second crop of paddy was to be raised in the monsoon periods, the bunds need to have strength to withstand the floodwater flows. If the traditional method of preparing bunds with clay dug out of the canal beds and stabilized with bamboo and coconut trunks was to be followed, there was a high risk of the bunds being breached by the strong waves and heavy currents during the monsoon. These bunds were indeed breached frequently and caused major crop losses if not reconstructed immediately. Thus, construction of permanent bunds, with a top width of 3 m, was considered a secure option.

The report [2] is of the opinion that even after the construction of the **Thottappally Spillway**, no significant improvement in the flood scenario in Kuttanad was observed. There were two major reasons for the inability of the Spillway to discharge more water. First, as more water was discharged from the Spillway, a sand bar was formed at the mouth. This sand bar reduced the amount of water that flowed into the sea through the Spillway. Every year, the government, to ensure that more water flows out into the sea, removed this sand bar either manually or using machines. This, however, did not help to increase water flows beyond a point. Secondly, the total capacity of the Spillway was not being realized because the leading channel of the Spillway on the east did not have the width as in the original design. Further, due to the meanders in the path of the leading channel, the velocity of water flow reduced. As a result of these two factors, the amount of water that flowed out of the Spillway – even when all its shutters were open – was considerably less than its capacity.

Thanneermukkam Bund, being one large structure that considered Kuttanad as one homogenous entity, failed to account for the fact that different regions within Kuttanad had different levels of problems with regard to salinity intrusion. For instance, the areas of Vaikom, Thuravoor and Purakkad are outside the purview of the Thanneermukkam Bund and did not benefit from it. In other areas, like the northern part of Kuttanad close to the Thanneermukkam Bund, farmers used to put up temporary tidal bunds to prevent the entry of saline water even before the Bund was constructed. These were put up soon after cultivation began and were demolished soon after harvesting was completed. In parts of Upper and Central Kuttanad, the problem of salinity was never too severe to necessitate a large structure like the Thanneermukkam Bund. It was, thus, argued that the Thanneermukkam Bund, even if beneficial, would benefit only about 8000 ha of Kayal lands and another 10,000 ha in North Kuttanad. Secondly, it was argued that the Thanneermukkam Bund, by halting the entry of saline water into Vembanad Lake, would adversely affect the fish population of Kuttanad. Traditional fish species in the Vembanad Lake required an amount of salinity in the water to grow. In the absence of salinity for a long period between December and May, when the Thanneermukkam Bund was closed in the past, there was a fall in the population and diversity of fish species in the Lake. Thirdly, the absence of salinity in the Vembanad Lake was also argued to be the cause of the prolific growth of aquatic weeds in the region. These weeds were causing multiple difficulties: they polluted water, prevented navigation, depleted dissolved oxygen, ensured that no sunlight entered water and harmed fish growth.

AC Road was not supposed to be a road alone; it was supposed to be a **road-cum-canal**. A 40 m wide canal was to run parallel through the distance of the road. This canal was to drain out floodwater from Upper Kuttanad (the Changanacherry side) to the Vembanad Lake (near Alappuzha side) and thus to the Arabian Sea. The road-cum-canal was also, thus, to alleviate the flood problem in Upper Kuttanad. The construction of this canal has remained incomplete even today.

A major activity proposed by the water resource department under the Kuttanad package was the strengthening of outer bunds of padashekharam. [2] In the case of earthen bunds that are traditionally erected, floodwater pressure and tides result in frequent breaches. Farmers of Kuttanad deserve permanent outer bunds which can withstand the forces of water currents. Height of bund and materials used for bunding would depend on the location of the structure after compartmentalisation, maximum flood water level and flood pressure. Outer bunds also require side protection walls for protection from flood water currents and tidal flows.

M S Swaminathan Research Foundation report [3] had underlined the necessity of random rubble masonry and granite pitching in areas of bunds where strength was critically important. Wherever feasible, bunds could be made of stiff clay with appropriate slope in conjunction with bio- protection on the waterside. Eastern and southern sides of the padasekharams in Kayal area may have bear severe impact of monsoon winds and these sides hence require very strong bunds. For bio protection, different species of grasses including fodder grasses and other appropriate grass/shrubs may be chosen and established by using geo-textile as the binding material. Apart from such plant species on the waterside of the bund, one row of coconut could be planted on one side of the bund.

2.1. REPORTS ON FLOOD DAMAGE IN KUTTANAD IN RECENT PAST

A study on water balance in Kuttanad in 1989 highlighted that floods in the region have a return period or recurrence interval of two years, five years, ten years, 25 years and 50 years. According to this study, based on historical data, floods with a return period of 10 years are severe.

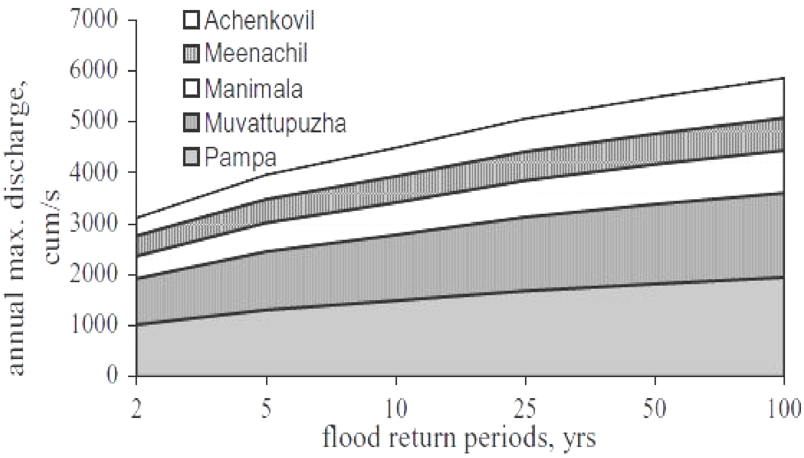

Figure 2. Return period of flood and their intensity [3]

In 2007, a report by MS Swaminathan Research Foundation titled ‘Measures to Mitigate Agrarian Distress in Alappuzha and Kuttanad Wetland Ecosystem’ [3] stated “increased frequency and period of flood and consequent losses arise from decreasing floodplain area including the Lake. The Thottappally Spillway (TSW) and the leading channel engineered to reduce the flood intensity in much of the Lower Kuttanad and the Lake area is declining over the years in its flood regulation capacity due to poor maintenance and lack of coordinated action on its operation. Farmers of Purakkad Kari in Kuttanad, where paddy is grown in 3,500 ha during monsoon season, are facing the brunt of this decreased flood flow capacity and inefficient management of spillway. Measures recommended to include modernisation of TSW, deepening and side bund protection of leading channel and improved management of spillway operation.”

Alappuzha faced one of the worst floods in the district in July 2007 when 1,34,000 people was evacuated to 664 relief camps in Kuttanad, Mavelikara and Chengannur Taluks. 212 houses have been completely damaged and 9,494 houses partially damaged. Strong currents aided by increased water flow from the high ranges along with non-stop rain shattered bunds at several areas in Kuttanad, damaging paddy worth crores of rupees and sweeping off an entire house in Kainakary. In Kainakary, Aaarupanku and CheruKayal paddy fields and houses alongside the canals in the area were among the worst affected, with water rising to more than six feet in some areas. Meanwhile, residents of Kainakary and other areas in Kuttanad are slogging round the clock to repair the breached bunds and to prevent further breaches. Near Aarupankukara, where a breach swept away a house, two more houses on either side of the breached bund are facing the threat of being washed away. (Reported in ‘The Hindu’ on Jul 21 and 22, 2007).[4]

In 2010, the Kuttanad wetland ecosystem development package was implemented. The package included proposals for ecological restoration, flood control, development of agriculture and fisheries, sanitation and drinking water supply. However, the progress of this project was very slow and later in 2017, the package was revived to gain ecological security of the region.

The worst floods to hit the state in the last two decades were in monsoon season of 2018 which had ravaged the Kuttanad region. The floodwater had submerged the entire region and forced a large number of families to leave their homes. The water level in the region increased to dangerous levels owing to heavy downpour in those days and flow of water from neighbouring areas. Officials said that the Revenue Department had opened 375 gruel centres in Kuttanad Taluk for 86, 839 people of 22,120 families. Officials added that hundreds of families had been displaced and were staying with relatives or living in temporary shelters. The floodwaters breached bunds across the region and flooded houses and destroyed paddy cultivation. The floodwater submerged large tracts of paddy fields. As per the statistics available with the Agriculture Department, flood has ravaged paddy cultivation in 7,316 ha. (Reported in ‘The Hindu’ on Jul 18, 2018).[5]

Figure 3. Bund breach during flood

During July and August 2018, Kuttanad had witnessed floods three times one after the other which forced lakhs of people to leave their houses. A total of 575 houses were fully damaged and as many as 2,726 houses were damaged up to 30-59% and 922 houses which have damages between 60-74%. Kuttanad, which is one of the worst flood-affected parts in the state is slowly back on its foot. Still, Kuttanad has been facing floods at intermittent intervals.

During floods 2018, “due to such high rainfall, there was an absence of appreciable storage in reservoirs upstream, along with the shrinkage of carrying capacities of lakes, rivers, and the porous land. The limited capacity of Vembanad Lake and Thottappally Spillway worsened the flooding in the Kuttanad region and the backwaters. Many areas were submerged under water for more than two weeks,” says Post Disaster Needs Assessment.

The study report on Kerala floods of August 2018 of the Central Water Commission (CWC) also gives a thorough hydrological analysis of the effects of the heavy rainfall on the Muvattupuzha, Meenachil, Manimala, Pamba, and Achankovil rivers that drain into the Kuttanad wetlands.

III. BUND CONSTRUCTION AND PROTECTION TECHNIQUES ADOPTED IN KUTTANAD

Typical bund construction techniques which are adopted conventionally in the past is as follows: The process of reclamation of land for cultivation would start with identification of the shallow regions in the vast stretches of Vembanad Lake. Mark the boundaries by erecting bamboo poles, which are subsequently protected with construction of strong bunds around the boundaries. The bund construction and maintenance are highly skilful tasks, for which an array of long and stout coconut poles would be hammered deep enough into the lake bed in two rows, normally in 1.5 m to 2.5 m width enveloping the entire area and fenced with bamboo (both yellow and green ones) mats on either side. The side walls would be then protected with frames made from aracanut poles and covered with woven coconut leaf plates. The channels of the bund would be filled to the desired height, first with sand, followed by twigs, sedges like Typha and Sheoneplectus (Korapullu) and dead materials usually brought from distant places. These would be interspersed with high quality clay that dug from 20-25 m deep bottom lakes. Clay digging which is also called Kattakuth, would involves diving 20-25 m deep into the Kayal-bed, a task which needs high physical strength, skill, experience and ingenuity for the persons engaged. On an average, 400 to 500 men are engaged in a year to complete the reclamation process of land about 2000 ha size.

Outer bund construction and strengthening around padasekharams is critical to prevent frequent eruption and the resultant distress from flooding related crop loss. Strengthening of these bunds in accordance with the level and force of floodwaters is important to prevent breaches and consequent serious crop losses. As the dyke’s bursting pose threats to lands of every individual involved in reclamation of lands there would be coordinated effort to immediately repair such damages. The padasekhara committees are made responsible for the annual maintenance of bunds. Individual farmers of each padasekharam, on the basis of the area they own, would share the cost of the maintenance work of the bunds. Similar maintenance for de-silting of adjacent canal is done collectively, once in 4 or 5 years. Normally bunds would breach during high flood and high tides. Since last 20-30 years some of the padasekharams are protected with permanent outer bunds with granite pitching, which has substantially reduced the risk of breach and crop loss.

Once the construction of bund is done, dewatering is the next major task. Dewatering the fields would commence after the wet ploughing and the completion of repairs to the outer bunds. Traditionally, huge and strong water wheels of 10- 12 feet diameter with blade width of 1 to 1.5 feet were used, which pedaled by 12-14 men who work from a gallery erected for this purpose. The water wheels normally used has 4 to 18 leaves. Water is pumped out generally into the surrounded lake or the canals made outside. Normally the polder land base is 6-8 feet below the surrounding water level. Protecting the bunds from bursting due to the pressure of water outside bund and stormy winds and tidal action used to be the most tedious task. When dewatering is completed, the smaller inner bunds that demark individual plots within each padasekharam are repaired. Along with this, repairs to inner irrigation canals are also done. Water inlets in the polders are closed by grass or wood. Outer bund also serves as a temporary threshing ground and storage place for threshed grain. Once the dewatering is completed, rice cultivation process that has the standard of practices with some variation will start.[6]

Figure 4. Bund Construction in Kuttanad

Random rubble masonry is one of the methods practiced for bund protection in Kuttanad region.Masonry protection is essential in sections subjected to high searing action and flood pressure, which may not be resisted by clay bund. Masonry offers a high resistance against rotting, pests, weather, and natural disasters. Being durable and resistant, masonry can withstand large amounts of compressive weight loads and have longer lifespans.The stability of masonry structures depends completely on their foundation. If any settling of the foundation occurs, cracks are likely and they must be repaired to prevent moisture infiltration and damage. During the dredging or widening operations carried on nearby water bodies, chance for the damage of masonry foundation is higher which leads to the further breaching of bunds. Masonry construction requires a good amount of time and adequate project planning. Depending on the type or masonry, specialized manpower may be necessary.

Another innovation method was identified by the coir board. They introduced biodegradable geo-textile for the stabilisation of bunds. Coir Bhoovastra is one of the commonly used geo-textile in Kuttanad. Coir Bhoovastra are permeable fabrics made from coir fibre extracted from coconut husk either by natural retting or by mechanical process. Coir geo- textiles are used for stabilisation of soil through vegetation against erosion of landscape and soil slopes as well as for the protection of banks of river, canal and lakes, road and railway embankment, reinforcement of mud wall of stream, bunds, farm and fishponds against erosion and other applications involving separation and filtration. Coir Bhoovastra can initially hold the ground for seeds and seedling and it can provide mechanical support against water erosion and it can help in the germination of seeds better and growth of the plants. It can stay on the earth against the ravages of quick flowing water, wind or wild vegetative growth. The openings between the strands give the grass or vegetation plenty of growing room.

Another geo-textile recently introduced for bund protection is the cocolog. Cocologs are made from coir fibre bunches under pressed condition in tubular enclosures of knotted coir yarn. Cocologs are mainly used for protection of vulnerable streams, rivers or lake banks. They are similar to a wooden log in shape. They are available in various diameters, length and weight. The diameter usually varies from 30 cm to 50 cm, weight from 60 kg to 180 kg and the most common used length is 6 metre.Charcoal is also used intermittently for filling the logs as additional manure for faster growth of plants. The rolls are attached at the edges of the bank and secured by wooden stakes/ pegs. The pegs may be used on alternate sides of the log. For high embankment areas with variable water level, several Cocolog can be applied as a stack.

Figure 5. Cocologs used for Bund Construction

IV. CASE STUDIES

4.1. Flood Control Techniques in Netherlands

One-third of the Netherlands is below sea level, and two-thirds is vulnerable to flooding. Dutch identity and society arose from the common need to push back against the sea. The Netherlands is situated in a low-lying delta formed by the outflow of three major rivers: the Rhine, the Meuse and the Scheldt. In accordance with the Dutch saying that "God created the world and the Dutch created Holland," the country is in large part an engineered landscape reclaimed from swamps and marshes. The Netherlands developing innovative water management techniques and technologies, a massive movable storm surge barrier that can be engaged to protect the city and port of Rotterdam from flooding, sits open, with its two swinging gates resting on dikes on either side of the NieuweWaterweg channel. The barrier, completed in 1997, was part of the last phase of the Netherlands' decades-long Delta Works project.[8]

4.2. Stability Analysis of Flood Bunds in Pakistan

Noshin, S. et al. [9] conducted study on flood bunds in Pakistan which lies in the Indus Basin and faces severe threats and losses from the floods since histories. Flood bunds are the earthen hydraulic structures which are constructed along the River to control the Flood water to avoid damages to the infrastructures, crops, livestock and loss of human lives. About 6807 km length of flood embankment has been constructed to safeguard against the floods in the country.

The study was done in Punjab, the worst hit province by heavy floods and rains causing heavy loss. Geotechnical Evaluation is vital for proper functioning of such structures. In this study four flood bunds susceptible to potential embankment breaching during flood were selected along the river Chenab in district Muzaffargarh Irrigation zone. Suite of analysis using GeoStudio software (SLOPE/W and SEEP/W for stability and seepage analysis respectively) has been performed by considering four different critical scenarios, (1) steady state at highest flood level (2) rapid drawdown from highest flood level (3) steady state at extreme condition with 3 feet free board (4) rapid drawdown from extreme condition with 3 feet free board. The safety of the flood bunds is evaluated in terms of River Embankment Breaching Vulnerability Index (REBVI), safe exit gradient and factor of safety against slope failure. The study recommended to make embankment impervious using cohesive material and to install cut-off walls or berms to lengthen the seepage path.

4.3. Flood Protection Works at River Alakananda, Uttarakhand

The Flood protection technique used in River Alaknanda in Uttarakhand presents an interesting case. Here, the opening of the Joshiyara barrage gates caused rapid flow fluctuations in the flow of river Alakananda, leading to erosion of the left afflux bund and its slope. The height of the bund was also considerably reduced, resulting in the inundation of the nearby countryside downstream of the barrage. To address this issue, advanced and flexible solutions to protect the bund and prevent flooding of the adjacent countryside were arrived at. The toe instability was prevented by constructing a gabion wall over the existing reinforced cement concrete (RCC) toe wall. Reno Mattresses were added over the gabion wall for surficial protection. Reno Mattresses were also installed below the gabion wall and in front of the RCC toe wall for protection against scouring at toe for the river side. A similar pattern was adopted also for the countryside facing the bund. This solution allowed to considerably increasing height of the bund up to the required HFL with safe free board for prevention against flooding of the adjoining countryside areas.[10]

V. CONCLUDING REMARKS

The initiatives primarily made by the government for improving the water level control in Kuttanad is not effective in heavy monsoon season owing to the ingress of water from adjacent higher areas and causing bund breaches making the paddy cultivation a challenging task. The lack of proper flood control measures is badly affecting the livelihood of farmers in the region. The paper has highlighted these issues using data from recent floods and aims to explore the root causes of bund breach. The case studies of Netherlands, Pakistan and Uttarakhand are some of the solutions proposed for solving the issue. This may not be fully applicable for Kuttanad due to variations in soil conditions, climate and level of infrastructure cost. Most suitable method for bund protection in Kuttanad needs to be identified in similar lines. The ultimate aim of such a bund protection system should be round the year suitability with minimum cost and should be environment friendly.

REFERENCES

[1]. Kaushal, R., Ghosha, P., Geilmann, H., (2016), "Fingerprinting Environmental Conditions and Related Stress Using Stable Isotopic Composition of Rice (Oryzasativa L.) Grain Organic Matter" Ecological Indicators, Vol.61, part 2, pp 941–951
[2]. Kerala State Planning Board (2019), "A Special Package for Post-Flood Kuttanad", Kerala State Planning Board report
[3]. Swaminathan, M. S., (2007), "Measures to Mitigate Agrarian Distress in Alappuzha and Kuttanad Wetland Ecosystem", M S Swaminathan Research Foundation
[4]. The Hindu, (1 July, 2017), "Rain causes heavy crop loss in Kuttanad"
[5]. The Hindu, (18 July, 2018), "Worst floods in the last two decades ravage Kuttanad"
[6]. Swaminathan, M. S., (2012) "Kuttanad Below Sea Level Farming System", M S Swaminathan Research Foundation
[7]. Coir Board, (2016), "Coir Bhoovasthra - an Eco friendly, Bio degradable Material for Soil Conservation and Rural Road", India International Coir Fair.
[8]. Iovenko, C., (2017), Earth magazine(online), Avialable at https://www.earthmagazine.org/article/dutch-masters-netherlands-exports-flood-control-expertise (accessed on 26/01/2020)
[9]. Noshin, S., Alam, M., Sadiq, S. and Mandokhail, S. J., (2018), "Stability Analysis of Flood Bunds: A Study on Geotechnical Health Evaluation of Embankments" International Conference on Advanced Engineering and Technology
[10]. Maccaferri Environmental Solutions Pvt. Ltd, (2017), Case History Rev:00 Construction of Left Afflux Bund Near Barrage Control Room at Joshiyara Barrage, ManeriBhali Stage, Available at: https://www.maccaferri.com/in/flood-protection-river-alakananda/(accessed on 26/01/2020)