Structural Measures for Flood Risk Mitigation in the Agricultural Field: A Review

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Abstract: *Flood is amongst the most common of natural disasters and its impact is one of the most significant disasters in the world. Most of the developing countries' economy is heavily dependent on agriculture which employs a large percentage of the population. Agriculture, especially crop production, is highly sensitive to extreme events specially flooding. Flood risk mitigation is one of the practical methods in damage reduction in agricultural sectors. This paper attempts to analyse the review on mechanism of flood risk mitigation in an agricultural field to reduce the losses. Availability and implementation of structural measures on flood risk is limited Lack of such idea is also known to be an obstacle for strategic planning in most of countries. Therefore, the primary objective of this paper is to review the structural measures for flood risk in an agricultural field to overcome flood impact on agricultural field.*

Keywords: *Flood, structural measures, agronomic practices, extreme event.*

1. INTRODUCTION

Flood is natural hazard with complex consequences of both direct and indirect effects of geomorphological, economic, social and ecological. Its hold about one third (34%) of the total number of natural disasters produced worldwide. (Magdelaine, 2010). Causes of floods are due to natural factors such as heavy rainfall, high floods and high tides, etc., and human factors such as blocking of channels or aggravation of drainage channels, improper land use, deforestation in headwater regions, etc (Tingsanchali, 2011). The agricultural sector of Sri Lanka, like in most developing nations, is crop based and is the primary source of employment to the rural populations (Devendra, 2002). It accounts for 18% of the GDP, and 60% of the population largely depends upon this component for their livelihood. It also provides employment directly to 32% of the population. Furthermore the agricultural sector is principally crop based, which consists of the plantation and non-plantation sectors. While the plantation sector provides some 1.5 million people employment, it contributes to 15 – 16% of the agricultural GDP (Kelegama and Babu, 2005). Precipitation extremes (i.e., droughts or floods) are also detrimental to crop productivity. Higher heavy precipitation and flooding regimes could increase crop damage in some areas, due to soil water-logging, physical plant damage, and pest infestation (Rosenzweig *et al.,* 2002).Therefore, flood mitigation is one of the primary concept to prevent the flood damages in agricultural fields. Flood mitigation includes structural flood control measures such as construction of dams or river dikes and non-structural measures such as flood forecasting and warning, flood hazard and risk management, public participation and institutional arrangement, etc. (Tingsanchali, 2011). Some adaptations will likely be successful (e.g., change in planting dates to avoid heat stress), while other attempted adaptations (e.g., changing varieties and breeds, altered crop rotations, development of new agricultural areas) may not always be effective in avoiding the negative effects of droughts or floods on crop and livestock production. Importantly, there are additional dimensions to adaptation, related to social and cultural aspects that might either favor or hinder adoption of new techniques by farmers, depending on community dynamics (Smith *et al.,* 2003; Smit and Skinner 2002). Therefore, the primary objective of this review is to identify the structural measures to mitigate the impacts of flood in the agricultural fields.

2. Discussion

In order to mitigate the impact of floods, appropriate flood management measures have to be implemented. These measures can be classified into structural measures, non-structural measures and Integration of structural and non-structural measures. Structural Measures includes protection of the vulnerable area up-to certain level of flooding and preferred by engineers and local people. Non-structural measures focus on reduction of loss or damage which referred by social scientists and conservationist. Integration of structural and non-structural measures is essential for effective disaster management. Effective land and water management of protected and unprotected areas, involving compartmentalization, drainage, irrigation, drainage decongestion, land-use, cropping patterns, environment, ecology, erosion/ sedimentation control, etc. (IUCN, 2004).

2.1 Engineering measures

Storm water retention can be achieved by constructing basins or ponds that temporarily store surface runoff and release it at a controlled rate. Reduction of surface runoff can be achieved by other measures such as increase infiltration, evapotranspiration from the catchment (Grant, 2017). The creation of more wetlands which can act as sponges, soaking up moisture and wooded areas can slow down waters when rivers overflow. Halting deforestation and wetland drainage, reforesting upstream areas and restoring damaged wetlands could significantly reduce the impact of climate change on flooding, according to the conservation charity (Grant, 2017). Temporary barriers or flood barriers can also be added to permanent flood defenses, such as raised embankments, increasing the level of protection. “As the threat and frequency of flood risk increases, the use of passive flood defense has to be the only realistic long term solution (Grant, 2017).

Dikes are barriers or walls built to protect the land from water damage. They can be built using soil, stones, rocks, sand bags or wood. Properly built, dikes can protect crops from flooding. A dike can slow water flow (for example, if made of stone) or divert water (in the case of clay or concrete dikes), or direct water flows to specific crops or other locations such as an irrigation channel (Learn.tearfund.org, 2018). Dikes, levees, and floodwalls protect a portion of the floodplain from flooding, up to a design level. These works may have adverse as well as beneficial effects. They can increase the height of the flood immediately upstream, across the stream, and downstream by reducing the amount of floodplain area available for overbank floodwater conveyance and/or storage. Their appeal lies in their direct and specific results. Sometimes emergency dikes or levees are built following a flood forecast. Although they may be effective for the emergency, they should not be considered as permanent flood protection measures. (Removal of emergency measures often does not occur because of cost and passing interest.) (Practicalaction.org, 2018). Storage of floodwaters in reservoirs causes the broadest range of flood-modifying effects such as reduction in flood flow rate, extent of area flooded, timing, etc. Except in the area immediately downstream from the dam, however, storage may not provide as high a degree of relief from flood damage in specific areas as may be achieved by other more localized tools. Flood storage may function alone, in groups, or with other tools (Practicalaction.org, 2018).

Blanket bogs in the uplands are made up of wet peat soils which are, in their healthy state, saturated for most of the year. Because they are already saturated, upland blanket bogs do not contain any great potential for the storage of water in flood risk events. Drainage networks in upland blanket bogs act to lower the water table, hence increasing soil moisture deficit and increase the water storage potential of these environments. However, drainage channels in upland peat bogs is in direct conflict with conservation management of peat bogs and negates the biodiversity and carbon storage functions of these habitats. A healthy peat bog can also attenuate flooding by slowing the movement of surface and sub-surface water from heavy rainfall events because of the rough surface vegetation. Peat lands with tall woody or coarse vegetation, many small surface depressions and pools and with little surface channel connectivity will tend to hold surface water for longer, so delaying water discharge to downstream channels (Carroll et al., 2006). Raised bogs which occur in lowland landscapes, generally in the middle reaches of a catchment, have a complex relationship with floodwaters. These midland raised bogs have mostly been drained and harvested for milled peat and for turf, so that only a tiny proportion of these raised bogs remain intact. Of those that remain, many have had drainage channels cut through them to dry out the peat in preparation for harvesting. While this is ecologically detrimental because it removes the conditions that characterize the bog and sustain the many flora and fauna that depend on these bogs, it is not necessarily negative for flood storage capacity. As with blanket bogs, drainage increases the soil moisture deficit of the peat surface, thus enhancing soil water storage capacity. However the channels also speed water flow to channels thus exacerbating flooding (Scottish EPA, 2015).

2.2 Agronomic and biological measures

Another structural measure of flood mitigation is agronomic and biological measures in agricultural lands. Improve the soil conditions is the one of the flood prevention plan because inappropriate soil management, machinery and animal hooves can cause soil to become compacted so that instead of absorbing moisture, holding it and slowly letting it go, water runs off it immediately. Well drained soil can absorb huge quantities of rainwater, preventing it from running into rivers (Grant, 2017). Land treatment measures modify floods by increasing infiltration and decreasing the amount and rate of runoff. These measures may also be viewed as modifying susceptibility to flood damage. They include vegetative cover, runoff interceptors and diversions, small detention and erosion control structures, terraces, and cropping management practices (which also serve to modify susceptibility to flood damage). They are effective in small headwater areas and function in combination with other measures to ameliorate flood conditions in larger watersheds. In most respects, land treatment measures produce changes in the broad range of flooding effects, although they become less effective as flood size increases. They can be especially important in reducing erosion and the resulting amount of sediment and pollutants carried downstream (Anon, 2018). A grassed waterway is a natural or constructed channel that is shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff. The primary purposes of a grassed waterway are to convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding and to improve water (US EPA, 2018). Every cubic meter of water that is retained through reclamation of floodplains, renaturation of surface water bodies, unsealing of land, seepage and site-appropriate agriculture and forestry, as well as through the preservation and promotion of small landscape structures for water retention, is a benefit for the ecosystem and relieves us in the case of flooding" (LAWA, 1995). Different ways of protecting crops include keeping ploughed soil covered by mulch or cover crops; planting trees and hedges around fields to reduce run-off; building dikes and irrigation channels/pipes to control the flow of water onto crops ; improving drainage through raised beds, ridges or mounds; planting early-maturing crops to avoid the flooding season; planting flood-tolerant crops; promoting floating gardens in flood-prone areas; building flood-resistant storage facilities for grain and accessing information on risk and weather forecasting to work out the best planting time. When the soil is not covered by vegetation, mulch or crop residues, it will be more exposed to the impact of rainfall. When the soil is protected by mulch, adjacent trees and shrubs, or cover crops (these are usually leguminous crops such as pigeon peas, lablab, velvet beans etc.), the water flow is slowed down, so the water has more time to infiltrate into the ground rather than run off the land, washing away high nutrient soil with it (Learn.tearfund.org, 2018).

Planting hedges along the contour of a field can also help to intercept runoff, in addition to the roots of hedgerow trees aiding infiltration of water. As with other natural flood management measures, hedgerow planting will only achieve flood alleviation service if targeted at the right locations, in this case planting along contour lines, on specific slopes where runoff should be targeted, and in floodplains (Lunka, and Patil, 2016). Similarly, agroforestry, by incorporating tress in to productive agricultural land as both a crop and a shelter for stock, has been shown to greatly increase soil water infiltration capacity, thus slowing run-off and contributing to flood attenuation. Evidence shows that there are significant merits for reducing local flood risk by having fenced-off tree areas in silvo-pastoral settings (Lunka, and Patil, 2016). Natural buffers such as coastal wetlands can play an important role in attenuating seaward flooding. Salt marshes, found in sheltered areas of the intertidal zone, dissipate wave energy and provide defence against tides and waves, particularly during stormy conditions. They also have a large storage capacity for high river levels or high tidal levels. This will be of most benefit in narrow inlets, bays and natural harbours, such that the tidal flow cannot be displaced along the coast. Even a small width of fronting saltmarsh can significantly reduce the height of sea walls required to achieve the same level of protection and thus initial construction costs (Scottish EPA, 2015.)

Crops can be grown in raised beds, on ridges, or on mounds to improve drainage. Ridges help to drain excess water, keeping it away from the plants. Excess water can be drained if there is somewhere for it to go, or a storage pond could be dug at the lowest part of the garden/farm to store surplus water and allow it to soak into the subsoil slowly. The pond should be filled with stones or gravel to prevent mosquitoes breeding (Fao.org, 2018). Early-maturing varieties of crops are useful because they take less time to mature. It is therefore easier to avoid the flooding season. They are likely to be ready before, or can be planted after, the flooding season (Fao.org, 2018). People who live in areas regularly covered by water and who are unable to grow crops because there is very little available land, or land that regularly floods, can build floating gardens. Floating gardens are built using aquatic weeds as a base on which vegetables can be grown. (Fao.org, 2018)

Plant crops that are tolerant to flooding. Most root vegetables are naturally flood tolerant. And varieties of crops such as wheat and rice are being developed to be more resistant to floods (Learn.tearfund.org, 2018). In India, some of candidate genotypes has been tested and screened for resilience to different stresses using 'Mother' and 'Baby trials' and the promising varieties/ genotypes were identified through 'Participatory Varietal Selection' (PVS) approach and are being promoted among farmers, as the adaptation strategy to reduce vulnerability. Genotypes in this context are (i) ‘Swarna Sub 1’ and ‘IR 64 Sub 1’ of rice, which were found best under submergence conditions during flood. Swarna Sub 1 has been reported to yield 3.20 t/ha even after 10 days of submergence compared to yield of control variety (1.70 t/ha) under eastern conditions of India (Yamano *et al.,* 2013; Dar *et al.,* 2013). Manipulating the enzymes involved in the process may help us to cultivate new crops and even to weather-proof them. When oxygen is in short supply a plant’s stress response effectively shuts down its metabolism, and activates an alternative pathway that allows it to live for a short amount of time, with reduced oxygen. Scientists understood that a plant’s response to hypoxia is controlled by ERF transcription factors, proteins which trigger changes in gene expression. In turn, the stability of the ERFs is controlled in an oxygen dependent manner by a set of enzymes, the Plant Cysteine Oxidases (PCOs). The PCOs speed up the break down (degradation) of these transcription factors, via one of the cell’s protein removal and recycling systems, called the proteasome (Ox.ac.uk, 2018).

2.3 Mitigation measures practicing in different countries

Farmers are practicing rain forestation farming, bamboo plantation and river improvement to reduce the economic losses from flooding in agricultural field in Philippine (Dedeurwaerdere, 1998). Aquifer recharge through drilling and channelling of water to aquifer by drilling equipment for boreholes in large scale commercial and mono culture and mixed cropping in Jamaica (Balfour, 2008). Raised bed and network drains systems widely practiced in low land area susceptible to flooding in varied cropping systems by developing integrated inter farm drainage by drain digging equipment in Jamaica. (Balfour, 2008). It is practiced in extremely steep with high rainfall where mixed cropping farming systems by constructing a series of small dams (check dams) on small, steep stream channels to reduce overall water velocity in Jamaica (Balfour, 2008). Managing runoff with runoff attenuation features by using some methods such as woody debris places across streams, bunds intercepting flow pathways which store runoff and slowly release it over a day, points on the stream which spill into storage features on buffer zones and riparian zone management to Belford Burn catchment to reduce flood risk (Wilkinson *et al.,* 2010).

3. Conclusion and Recommendation

Agriculture is a key sector of world economy and also most affected by ongoing extreme events like flood. Impact of flood and mitigation techniques as shown by the studies reviewed, is a topical matter that engages the attention of many researchers in all over the world. This is probably due to numerous climatic extremes (floods and droughts) experienced in developed and developing countries. Adverse weather and climatic changes, capital shortages, high cost of inputs, access to credit difficulties, and poor quality of output are affecting agricultural productivity and impacting on the incomes of the farmers. However, adequate and relevant mitigation methods about impact of flood in most of agricultural countries are generally lacking. Successful flood risk management is obtained through structural measures are implemented. The implementation of multiple purpose measures enables municipalities to achieve multiple goals such as flood mitigation in agricultural field. Therefore different methods of structural measures are needed to maintain agricultural crop production under flooding effects. In conclusion, flood mitigation techniques will decrease agricultural losses by adapts new management practices in agricultural land.

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