

Stimulating Riparian Buffer on Agricultural Landscapes: A Review from Water Management and Climate Change Perspective in Ghana

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ARTICLE INFO

Article history:

Received: 10 July 2017;

Received in revised form:

10 August 2017;

Accepted: 21 August 2107;

Keywords

Riparian Buffer,
Agricultural Landscape,
Climate Change,
Water Management,
Freshwater,
Irrigation,
Dam/Reservoir.

ABSTRACT

The current and future states of Agriculture are challenged with limited water resource vis-à-vis global changing climate; erratic rainfall and drought potential, as well as rising temperatures causing evaporation of freshwater resources. There are equally many similar primary causes in addition to the threats outlined as they are directly linked with declining agricultural growth. Farmlands adjoined to freshwater sources (flowing stream), or constructed small-scale reservoirs are used for the purpose of irrigation on an agricultural landscape. Sedimentation, inorganic chemicals and nutrient loading from crop/livestock fields enter run-off into these water sources posing impairment challenges to the water body and thus, water quality and reservoir capture/holding capacity reduces. Hence, the urgent need for a sustainable approach to manage water resource especially on Agricultural landscapes characterized by this subject matter. The establishment of Riparian buffer system proves to manage these exacerbated effects adequately. Riparian is significant in environmental and natural resource management as they enhance water quality and biodiversity through its vegetative products and services in land-use systems. In a perspective, riparian buffer can be said to have a dual purpose by contributing to carbon sequestration as well as an adaptive measure in water management; to reduce rate of freshwater evaporation on Agricultural landscapes. Additional products such as food and medicinal benefits could be generated. This paper presents an archetypal Riparian buffer design suitable for replication in Ghana and other countries with emphasis on Agro-ecological gains, climate change resilience and natural resource management and conservation.

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1.0 Introduction

Water is among the numerous vital natural resources, it is imperative that water issues are not considered in isolation as it has a basic function in maintaining the integrity of the natural environment (UN-IWRM, 2014). Water resources can be classified into perennial and seasonal, with commanding range of uses such as agricultural irrigation, industrial, household or domestic and recreational activities. Baker *et al.*, (2006); FAO (2014); Alberti *et al.*, (2007) stated that, agricultural sites and deforested upstream generally results in widespread degradation of land and water resources, along with other negative environmental impacts accounting for much of the variability in water quality and stream ecological conditions. In practice, farming on a landscape within watershed catchment leads to considerable impairment to flowing water bodies (streams and tributaries) or captured freshwater in small-scale reservoir. Sediment transport and nutrients loading through run-off, slashing of vegetation (trees/shrubs and grasses) close to freshwater bodies expedites the increased risk of evaporation and so therefore these resultant effect.

There are great concerns about threats of the changing climate, precisely focusing on how much water will be lost

(Helfer *et al.*, 2012), in event, the magnitude of variability, timing and duration of how high and low the supply are unpredictable; this poses great challenges to water managers in particular and to societies as a whole (UN-IWRM, 2014). Rate of evaporation is driven essentially by meteorological controls mediated by the characteristics of vegetation and soils; climate change has the potential to affect all of these factors in a combined way that is not yet clearly understood (IPCC, 2001a). Farmers across the world have always had to cope with climate and weather variability, both small seasonal changes and large disruptive events (Sara, 2012). These effects could consequently lead to excessive shortage of water resources (Scarcity) and thus, makes it critical and dire, hence, the need for relevant management approach to mitigate its effect.

Lee *et al.*, (2003), concluded in a study that, best management practices of riparian can reduce the transport of non-point source pollutants in agricultural run-off before they enter surface water. Riparian ecosystem demonstrates significant nutrient removal from incoming fluxes (Mander *et al.*, 1997) especially from crops and livestock field. Complimentarily to this, management strategies such as use of the river continuum concept and vegetated buffer

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strips (Saunders *et al.*, 2002), can be effective approach to managing climate effect. Idassi (2012) explained that, Buffer strips and riparian zones around streams improve and maintain the overall integrity of the waterway and improve aesthetics. This can be achieved by planned development, distribution and use of water resources to meet predetermined agricultural objectives (Sara, 2012), landscape approach can rehabilitate degraded watersheds to improve hydrologic and water quality (UNDP, 2012). Forested riparian buffers offer many benefits not only to individual landowner's property, but also to the overall health of the entire watershed and everyone living downstream (www.tn.gov/). Adoption of Riparian buffer systems as part of the Agricultural Landscape management will stimulate Food Security as there will be sustainable water for irrigation, promote resilience to freshwater evaporation and other Agro-ecological functions in the context of water management. In this paper, key sustainable reforms from environmental perspective are highlighted for implementation in agricultural water management on a farming Landscape. United Nation (2014) mentions that, significant efforts had been made to develop and establish a uniform buffer policy for riverbanks, reservoirs, lakes, etc.

2.0 Designing a riparian Buffer

A buffer is a transition zone between two very different land types or land uses; gregarious along the margins of a river, stream or other water body that separates human-focused land uses, such as agriculture or development. It is managed for perennial vegetation (grass, shrubs, and/or trees) to enhance and protect freshwater predominantly from adverse impacts of agricultural practices. (www.unce.unr.edu/, and Dosskey, *et al.*, 1997), as shown in (Fig. 1 and 2). Riparian buffer could be established for both flowing water as well as captured water in small-reservoirs on Agricultural landscape for irrigation purposes.

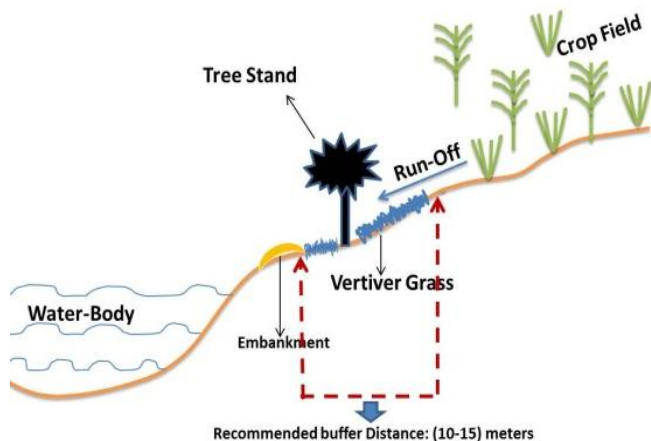


Figure 1. A Schematic Design of Riparian Buffer on an Agricultural Landscape

(Source: Authors own Construct, 2017).

Riparian forests provide important habitat for many wildlife species (Viegasa *et al.*, 2014), the location and distribution of wetlands and riparian zones influence the ecological functions present on a landscape (Baker *et al.*, 2006).

The first step in creating a buffer is developing a design that will work by first sketching buffer and identify major problem areas, list the cash crops to be considered and make sure those trees, shrubs, and grasses grow in your plant zone (Idassi, 2012). Agricultural fields that border a wide river, lake, or even a small stream in your backyard can be

improved by creating a riparian buffer (DeCecco and Brittingham, 2016). Research has shown that implementation of Best Management Practices (field borders, buffer strips, filter strips, grassed waterways, storm water management, and other practices) can significantly reduce sediments and pollutants originating with these land uses (Schnepf and Cox 2006). On agricultural landscapes where riparian buffer is established, freshwater are used for the watering of crops and livestock, rearing of aquatic organisms and domestic purposes such as drinking.

A new riparian policy in Ghana states that, the desired minimum buffer width should be able to sustain stream protection. Especially, if the land use involves animal feed operations or intensive chemical based farming (MWRWH, 2011). This study recommends between 10 to 15 meters (Approx. 32-49 feet) as a buffer zone for agricultural landscapes (Fig. 1). The policy moreover further delineates with a set of stream buffer categories. Thus, minor perennial streams: 10 to 20 meters, important seasonal streams: 10 to 15 meters, stream within forest reserves: 10 to 50 meters (MWRWH, 2011).

Sara (2012) stated that, most farmers in sub-Saharan Africa (SSA) live in areas with relatively abundant water resources with large areas of the continent receiving more than 1,000 mm of rain each year and possess significant groundwater resources with high rates of recharge (over 100 mm/year). This therefore presents the opportunity for all year cultivation if water is captured in reservoirs for sustainable farming as water is essential for crops and livestock survival along with conservation efforts such as riparian buffer system. As showed in (Fig. 2). Management practices are a necessity to healthy riparian zone (Mander *et al.*, 1997).

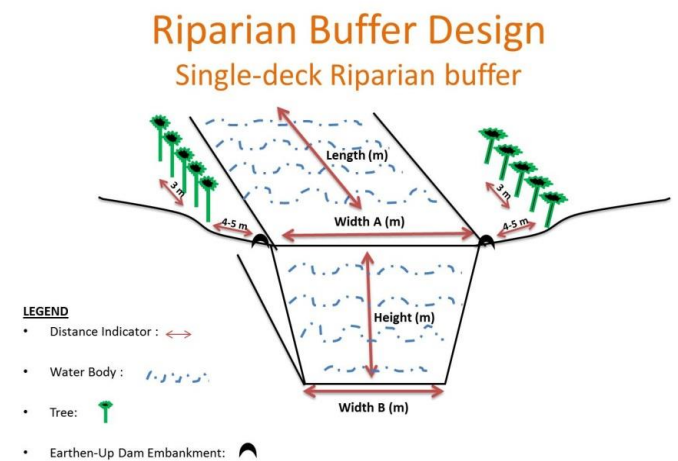


Figure 2. A Dimensional Layout of Riparian Buffer on a Small-Scale Reservoir.

(Source: Authors own Construct, 2017).

Planning and arrangements of trees/shrubs in riparian zoning on reservoir (see Fig. 2) requires complex factors to be in consideration such as, ecological function, hydrological relationship of the choices of trees/shrubs, and susceptibility of trees to harbor pest and diseases which could invade crop fields.

According to Gold *et al.*, (2013), spacing of trees should range from 10-15 feet between rows and 8-10 feet within the rows. The study adopted a single-deck riparian design with 3 meters (approx. 10 feet) within tree/shrub and 4-5 meters (approx. 13-16 feet) dimensions as the distance between the reservoir-embankment to the buffer zone see (Fig. 2). It should be noted that, the trees/shrubs should be within under-

storey vertivar grasses covering the ground (see Fig. 1). Usually riverine landscape native grasses such as *Pennisetum purpureum* (Elephant grass), etc. could be allowed to regenerate vegetatively. Some selected tree species for Riparian Buffer with Inundation characteristics have been highlighted (see table 1).

3.0 Riparian Management: Tree Regeneration and Strip Management

Preparing a site for tree planting depends on the existing cover of the site. Woody species planting is best done with seedlings; direct seeding can be done in some cases (Gold *et al.*, 2013). One needs to consider native plants that are available from local growers and nurseries, and avoid invasive species; plants that offer the most benefit as food, cover, and nesting sites, and include a mix of deciduous and evergreen species (DeCecco and Brittingham, 2016). Well managed riparian buffer on Agricultural landscape protect water quality, stop erosion of stream banks, improve habitat for fish and improve opportunities to make farm income through products harvested from the buffer (Idassi, 2012). This consideration varies greatly with respect to intention of set-up and geographic location as the survival of the tree/shrub for the riparian buffer depends on adaption to the natural environment. Tropical trees/ shrubs are conducive for tropical terrain and temperate plants thrive best under temperate conditions. According to UNDP (2012), trees and shrubs that are deep rooting and good shade producers will determine differences in soil moisture regimes, runoff and the export of sediment and nutrients into relevant water catchments. Gold *et al.*, (2013) iterates that, during the life of a forest buffer, trees will begin to compete with each other as they do in a natural forest, and without pruning and thinning they will not maintain an optimal growth rate. Practically, retaining existing trees, shrubs and grasses or other vegetation wherever possible in Riparian management are the best and lowest cost (www.nanaimo.ca/). Correspondingly, it is among the best practices to clear strip line where the seedlings are planted to support effective propagation, but this should be done with careful managerial planning.

4.0 Riparian Buffer and Climate Change

The impact of climate change on water resources depends not only on changes in the volume, timing, and quality of stream flow and recharge; but how its management and adaptations are implemented (IPCC, 2001b). According to FAO (2014), farmers and humanity as a whole are already facing the new challenges posed by climate change. Limanto *et al.*, (2016) states that, the extent of adverse effects that will be felt by farmers depends largely on the adaptation strategies they employ in response to climate change. Water shortage is a limiting factor to agricultural development (Loeve *et al.*, 2007). It is estimated that open water reservoirs will lose around 40% of their total water storage and conversely by 2040, the annual evaporation will be approximately 8% higher than the 20-year average annual evaporation estimated for the present climate in Australia (Helfer *et al.*, 2012).

A clear understanding of the issues and trends in agricultural water management is essential to support a national development policy that focuses on food security (Loeve *et al.*, 2007). There is a known fact that the climate in Ghana has changed significantly with impacts being felt especially on water resource as there is increased evaporation, decreased and highly variable rainfall pattern,

and frequent pronounced flood and drought situations (Asumadu-Sarkodie, *et al.*, 2015).

An integrated water resources management will enhance the potential for adaptation (IPCC, 2001b). Adaptations strategies could play an important role in mitigating the impacts of climate change (IPCC, 2001c).

Riparian Buffer functions over the long term and address potential future threats (like climate change) which may tend to impact negatively on runoff regime and the integrity of stream-side vegetation (MWRWH, 2011). Riparian forests shade the stream and regulate dry water air and water temperatures (Idassi, 2012). Sara, (2012) confirmed that, this systems of natural resource management contributes to carbon sequestration, rehabilitate landscapes, flood mitigation, erosion control, and improving efficiency carbon storage in soils.

5.0 Riparian Buffer and Water Management

Sediment transportation into water bodies through surface run-off leads to reduced storage capacity and some associated eutrophication problems. Lee *et al.*, (2003) emphasized the roles of riparian buffers for removing non-point source pollutants from agricultural area especially those carried by surface runoff. According to Hawes and Smith (2005) this makes it essential to the mitigation and control of nonpoint source pollution. Riparian buffers are able to remove both nitrogen and phosphorus at extremely high levels of concentration (Mander *et al.*, 1997). DeCecco and Brittingham (2016) also discussed this issue citing that; runoffs from agricultural fields are deposited in the buffer rather than being allowed to enter the water as the trees and shrubs along a stream bank help to further reducing sedimentation rates. It first filter's runoff and keep stream banks stable, helping to improve water quality by reducing the amount of nutrients and sediment that flows into waterways (USDA NAC, 2015). It is against this trickling mechanism backdrop why this paper suggested or recommended a buffer distance of between 10 to 15 meters (Approx. 32-49 feet) as a buffer zone for agricultural fields as shown in Fig. 1 above. To delineate further, about half-length of the buffer set-up will function as trapping continuum by the vertivar grasses found under-storey of trees/shrubs to capture pure sediments and dissolved plants nutrients in the run-off from the upstream agricultural landscape. Consequently, much of the nutrients especially will be absorbed by the trees/shrubs within the buffer for its growth; while the extra half-length of the buffer distance further filters the run-off to ensuring extremely low sedimentation and nutrient loading ability in the water body.

The buffer slows the velocity of runoffs allowing trapping of sediments. Hawes and Smith (2005) reported that, sedimentation increases turbidity and contributes to rapid siltation of water bodies negatively impacting water quality. Agricultural water management is the overarching term that covers soil and water conservation which involves maintaining or enhancing the productive capacity of the land, preventing run-off, inducing water infiltration, minimizing evaporation, collecting and concentrating rainfall (Sara, 2012). Taking a glance at the proliferation of reservoir/dam for irrigation agenda on Agricultural landscapes, an initiative of Government of Ghana (from 2017- onwards) to augment national rain-fed agriculture, an inadvertent constraint of sedimentation and evaporation are bound to occur, consequently, riparian buffer would be the best-fit mitigation approach in this instance.

6.0 Choice of Trees for Riparian Buffer

There are several forest tree/shrub species which regenerates natively on riverine landscapes or introduced for riparian purposes. Choices and selection can vary greatly depending on the agro-ecological benefit expected by the land-owner such as; shades, fruits and fodder, timber, medicine, sediment control, etc. It is important to consider the hydrological adaptation and interaction for riparian buffer establishment in the case of artificial introduction. Below are some of the popular and prescribed Tropical trees for consideration.

- *Mitragyna ciliata*: Subaha

FAO (1986) commented that, this tree characteristic of fresh water swamps where it is often gregarious, also common in narrow fringing belts along streams in high forest areas, grass plains and in low lying swampy areas of deciduous and evergreen rain forests. It has been found in swampy areas at high altitudes in Ghana and also present along riverine forests within the savanna.

- *Khaya anthotheca*: Black mahogany

Khaya anthotheca does best in deep fertile soils with subsoil moisture and can withstand seasonal flooding, it does well from medium to low altitudes and often riverine areas (www.worldagroforestry.org/>).

Table 1. Choice of Trees for Riparian Buffer and Inundation Characteristics.

Scientific name	Ghanaian Name	Inundation status and Tolerance	Products and Services
<i>Mitragyna ciliata</i>	Subaha	(E): Extremely High tolerant to Inundation	Watershed conservation (shade), Medicine, Timber
<i>Terminalia ivorensis</i>	Emire	(ML): Moderate to Low inundation tolerance.	A useful timber species Shade or shelter
<i>Nauclea diderrichii</i>	Kusia	(MG): Moderately does well and observed to thrive adequately to inundation.	Food, Folder, Medicine, Shade and Timber
<i>Khaya anthotheca</i>	Black mahogany	(G): Good tolerability to seasonal inundation	Watershed conservation, timber, shade, ornamental (avenue tree; promote biodiversity).
<i>Heritiera utilis</i>	Nyankom	(VG-E): Highly tolerability to inundation	Watershed conservation, Food, medicinal, Aphrodisiac, Timber, and shade

Note: (E)-Excellent; (VG-E)-Very Good to Excellent; (G)-Good; (MG)- Moderately Good; (ML)- Moderate to Low

- *Nauclea diderrichii*: Kusia

The tree is an evergreen tree; gregarious in the transition zone between freshwater swamp and lowland forest (Orwa et al., 2009b)

- *Heritiera utilis*: Nyankom

It growth is characteristic to both wetland and fairly moist soils. According to research, the tree is intolerant of drought and therefore thrive mostly in wetlands and a moist-soil landscapes (<http://tropical.theferns.info/>>)

- *Terminalia ivorensis*: Emire

The Emire tree can withstand short periods of inundation, though it is usually sensitive to waterlogging (Orwa et al., 2009a).

7.0 Conclusion

Water availability and quality for all-year round agriculture are said to be gradually depleting making it critical and dire amidst changing climate and several anthropogenic factors such as clearing tree/shrubs along riverine. Riparian buffer is said to have the multifaceted functions and therefore provides synergism of integrated water resource management on agricultural landscapes. This study also sought to promote riparian buffer establishment and adoption by private landowners, communities, Government and non-governmental organization as an approach to climate change adaptation and mitigation respectively in water management. Agro-ecological balance is also promoted in riparian systems.

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