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The Impacts of Saline-Water Intrusion on the Lives and Livelihoods of Gambian Rice-Growing Farmers

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ABSTRACT

In most developing countries, agriculture plays a key role on the livelihood of generations of poor rural farmers. Climate change is projected to undermine agricultural production and exert more stress on the livelihood of many farmers, including in The Gambia. Rice *Oryza sativa* L is the main dietary food in The Gambia and River Gambia serves as the country's major source of freshwater irrigation for tidal rice farming. River Gambia is seriously affected by saline water intrusion which in effect threatens the country's main freshwater source. This phenomenon is blamed on climate change as a result of sea-level rise coupled with the worrying trend of increase in temperature and decrease in rainfall. Consequently, rice growers who solely depend on tidal irrigation from River Gambia have encountered low rice production over the past years. Saline-water intrusion has significantly impacted the livelihood of Gambian rice farmers and this has led to farmers not cultivating their fields any more in some instances. This paper attempts to review the impacts of saline-water intrusion on the livelihood of Gambian rice-growing farmers, particularly for those involved in swamp rice cultivation along River Gambia. It is noticed that with increased climate change, the tributaries of River Gambia will become more saline. The saline-water intrusion will significantly impact the quality of water in the tributaries which in consequence will greatly reduce the productivity of the rice plant which is not saline-tolerant. As a result of saline-water intrusion in the rice-growing tributaries, food security of the rice-growing farmers in these ecologies is expected to be threatened. This paper recommends series of measures necessary to help farmers adapt to the negative impacts of saline-water intrusion as a result of climate change. These measures include but are not limited to regular monitoring of the salinity of the river and its tributaries, the construction and/or reinforcement of new embankments/dikes that prevent intrusion of saline-water in the rice-growing areas, review government policies that relate to frequency and volume of water that is pumped from the river that could enhance saline-water intrusion in the river, development and provision of saline-tolerant rice cultivars, and increase training support for rice farmers on best cultural and land use practices.

INTRODUCTION

The Gambia is one of the smallest countries in West Africa. It has a total land area of about 11,360 km^2, extending approximately 400 km eastwards with widths varying from about 80 km at the Atlantic coast to about 24 to 28 km in the east. The country is surrounded by the Atlantic Ocean to the west and Senegal along all other borders [1]. The country lies between latitude 13 and 14 degrees north, and 17 and 1 degrees west. The Gambia has a Sahelian climate, characterized by a long dry season (November to May) and a short wet season (June to October). The country receives from 850 to 1200 mm of rainfall ranges and the average temperatures range is from 18 to 33ºC. The relative humidity is around 68% along the coast and 41% inland during the dry season and generally over 70% throughout the country during the wet season. The river with over 1,130 kilometres of length is the unique water body feeding the country from East to West in freshwater. It naturally originates from Fouta Djallon

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highlands in Guinea Conakry and crosses the entire length of The Gambia and empties into the Atlantic Ocean. Its tributaries in The Gambia are: Sandougou, Miniminyang, Baobolong, Sofanyama, and Bintang Bolong which give existence to wetlands in the country. Those wetlands represent suitable lands for livelihood activities among which agriculture is the major activity. The Gambia's population is estimated at 1,857,181 people of which 943,426 (50.8%) are women and 913,755 (49.2%) are men. About 91% of the extremely poor and 72% of the poor in The Gambia depends on agriculture for their survival [2]. Furthermore, the agriculture sector alone in the country provides employment for about 68% of the labour-force and an estimated two-thirds of total household income. These figures indicate the contribution of agriculture to the livelihood of the people of The Gambia. The Gambia's preferred staple food is rice, which is traditionally cultivated primarily in the lowlands as a subsistence crop [3]. River Gambia provides freshwater for rice cultivation throughout the country with Lower River and Central River Regions recognized as the food basket of the country in terms of production. These areas are ideal for rice cultivation due to the existence of good climatic conditions, adequate soil and water quality, irrigation facilities, as amply demonstrated by the presence of several rice projects. In the tropics, changes in climate are essentially comprised of variations in weather patterns which are primarily associated with increase in temperature and decrease in precipitation. According to the Intergovernmental Panel on Climate Change precipitation will decrease in the sub-tropics and extreme events will become more frequent. In addition, sea-level rise is projected to extend areas of salinization of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas [3]. Climate change predictions, including sea-level rise suggest further exacerbation of salinity problems in the future. Moreover, anticipated impacts of climate-induced sea-level rise include direct inundation (or submergence) of low-lying wetland and dry land areas, erosion of soft shores by increasing offshore loss of sediment, increasing salinity of estuaries and aquifers, raised water tables and exacerbated coastal flooding, storm intensity and storm damage [4]. Many coastal areas in the world are threatened by or at risk of saline-water intrusion into freshwaters, groundwater, estuaries and lowlands. Among them, areas such as Atlantic Canada, Clyde in Glasgow, the Vietnamese Mekong Delta, Bangladesh, the Nile Delta, River Senegal and River Gambia (in West Africa) are amongst areas of growing salinization in the world. Salinization of freshwaters is being aggravated by factors such as river water runoff, warm weather and intense evaporation [5]. Saline-water intrusion (or salt water intrusion) is the encroachment of saline-water, usually from the sea or ocean into fresh surface or ground water regions in coastal aquifer settings [6]. Africa has been named as one of the most vulnerable continents to changes in climate, and The Gambia will be especially affected by this phenomenon [7]. The Gambia is ranked among the top ten countries in the world with the highest share of population living within the lower elevation coastal zone (LECZ) [8]. The Gambia's geographical position predisposes it to drought, windstorms, coastal erosion and sea-level rise [9]. Owing to this fact, the country is threatened by saline-water intrusion resulting from the combination of sea-level rise and decrease in rainfalls. Therefore, the biggest threat of saline-water intrusion into River Gambia and coastal aquifers comes from projected sea level rise [10]. River Gambia is the dominant geographical feature of the country and a potentially significant freshwater resource, although the existence of extensive saline-water intrusion as far as Georgetown and Bansang further upstream, reduces its role as a feasible water resource [11]. Generally, saline-water intrusion makes the river water unfit for human consumption and unacceptable for irrigation practices [12]. With the projected climate change phenomenon, the saline front is expected to move upstream by about another 37 kilometres, thus reducing land availability and suitability for irrigation and crop production [13]. Salinity is a major problem for rice production in The Gambia and it affects a considerable number of farmers especially those who are on lowland areas [14]. Therefore, wetlands and freshwater of River Gambia are at risk of serious saline-water intrusion, including flood plains well-known in The Gambia for rice farming and vegetable cultivation. Currently, the existing literature on salinization of River Gambia is based on modelling and water quality scenarios. There is obviously a dearth of knowledge regarding factors influencing salinization and the associated implications on the lives and livelihoods of the Gambian farmers.

This paper discusses saline-water intrusion phenomenon in River Gambia with emphasis on the causes, dynamics and livelihood impacts of the affected communities. It further deliberates on the importance of River Gambia to Gambian farmers and suggests a comprehensive way of adapting to the adverse effects of saline-water intrusion as impacted by climate change.

MATERIALS AND METHODS

To carry out the study, a desk or literature review of the country's documents on agriculture (published or non-published), was conducted. The review also covered the country's saline-water intrusion phenomenon and its impacts on rice cultivation. The information collected was subjected to critical scrutiny and analyses to support the discussions and findings.

RESULTS AND DISCUSSION

Causes and Dynamics of Saline-Water Intrusion In The Gambia

The phenomenon of saline-water intrusion was reported for the first time in the 19th century. The phenomenon comes from a combination of several factors. These factors are grouped into two main causes, namely natural causes and human-induced causes. The natural causes are comprised of topography of the country and tidal flooding and back water effect. For the human-induced causes; groundwater abstraction, increased temperatures, slow-onset and reduced rainfalls and climate change-induced sea-level rise were identified.

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Natural Causes

Topography of the country and tidal flooding

The Gambia experiences semi diurnal tide. The country faces two flood tides and two ebb tides within a day in a 6-hour consecutive time interval. During the river's low tides, an overflow saline-water from the sea surrounding the coastal region intrudes into the river. The low-lying physical characteristic of the country is a natural contributing factor which can accelerate saline-water intrusion into River Gambia during periods of river low tides or pronounced drought spells. Thus, saline-water from the Atlantic Ocean enters into the river and spreads out in coastal and lowland areas of the country. The estuarine reach of River Gambia is characterised by low-lying topography, a tidal range in the meso-scale (2–3 m), highly seasonal freshwater inflows upstream ranging typically from 2 m^3/s in the dry season to 500 m^3/s in the rainy season [11]. This has resulted in seasonal saline-water intrusion into the river. Due to the large variation in river flow and the flat nature of the country's terrain, River Gambia is tidal, and thus saline, for much of its length [11]. Naturally, sea water intrudes into River Gambia estuary according to an annual cycle interlinked to the continental fresh water flows. At 250 kilometres from Banjul, an average of 1 g/l salt or 1.5 ms/cm front is situated by the end of June/July [15]. **Figure 1** below illustrates the natural process of saline-water intrusion into River Gambia.

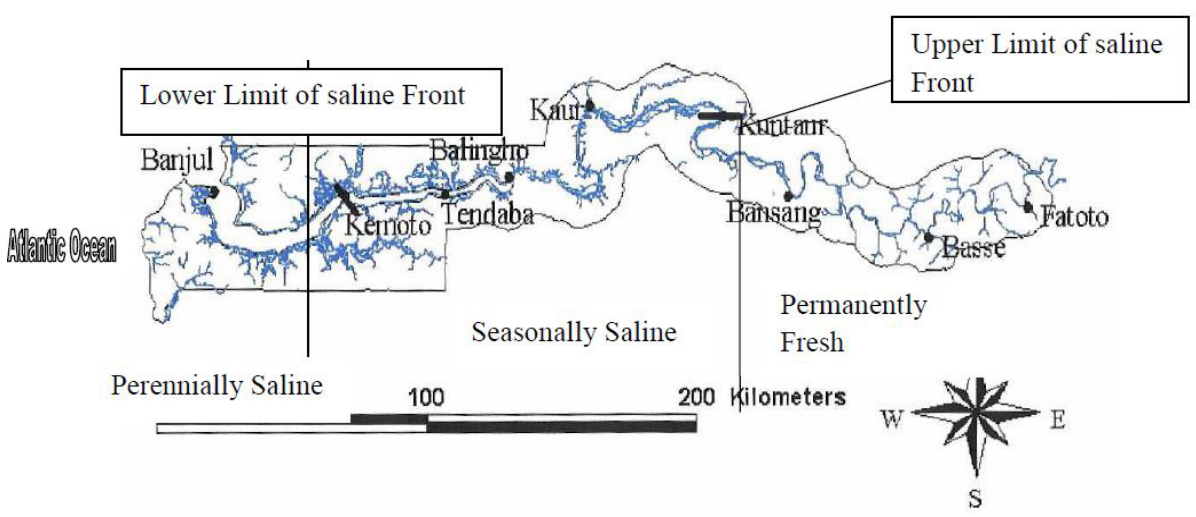

Figure 1. Zonation of river Gambia estuary [5].

Because the flow of the river is markedly seasonal, the salt front moves up and down the river over the course of the year. Then at the end of the dry season in May, the river's flow increases and reaches peak flows during the raining season which stops by end of September towards early October. From November to May, the salt front migrates eastwards and enters very well in the middle reaches of the river. This is due to the extremely flat character of the river. According to because the landscape of the river is extraordinarily flat, the great tidal movements of the Atlantic Ocean are transmitted up the river [16].

From kilometre 110 to 180, the freshwater is only seasonal. Its duration depends upon the amount of rainfall. It represents the seasonally saline zone where tidal agriculture is possible. This zone is found in the Lower River Region where the entire zone encompasses riverine seasonally saline swamps. This situation has many implications on the livelihoods of rice farmers whose activities depend largely on the river for tidal irrigation. This is where this study comes to bring out the impacts of saline-water intrusion on rice production from swampy fields As far as the Government of The Gambia is concerned, climate change represents one of the country's greatest burdens and challenges for development and poverty alleviation, because the economy and the people rely on activities such as agriculture, livestock, energy and water for their lives and livelihoods.

Back water effect

Backwater effect is a special type of saline water movement which takes place at the mouth of the river when fresh water is not sufficient enough to counteract tide water moving towards the river from sea [17]. Swamps nearest the river receive daily tidal flows charged of minerals from the ocean waves while those farther back experience inundation with lunar tides or occasional riverine flooding. The latter, outside of daily tidal reaches receive small alluvial deposits and therefore, require supplemental fertilization while the first area which is seasonally saline is at risk of acidification.

Human-induced causes - groundwater abstraction

Literature indicates that saline-water intrusion is a multi-casual phenomenon resulting from many factors. Besides low rainfall resulting from climate variability and change which can exacerbate the natural-balanced saline-water intrusion, factors related to groundwater resource abstraction can contribute to incremental salinization of ground water and further to surface

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waters. It is established that water demand for pump-irrigation in The Gambia accounts for more than 70% of the total demand in water. Taking into account the increase in demand for domestic use, thanks to the population growth, the salt front is possible to move further and prolongs the saline zone for some more kilometres upstream. The dramatic increase in saline intrusion in the dry season at higher abstraction rates is self-evident in the country [16]. Therefore, current and future human activities, especially extensive and unplanned groundwater abstraction will contribute to create depressions in the ground which will be filled by saline-water from the Atlantic Ocean. If the rates of groundwater abstraction exceed the recharge capacity of aquifers (through infiltration and percolation), the interface saline-water and freshwater aquifer moves further upstream. This will possibly deteriorate the available groundwater resources and increase saline areas around coastal, delta, estuaries and in inlands.

Increased temperatures, slow-onset and reduced rainfalls

It is established that, climate parameters such as precipitation, surface runoff, and temperature can play a big role in affecting saline-water intrusion. Indeed, with lower amounts of precipitation and warmer temperatures, the recharge's rate of River Gambia will be much less due to insufficient groundwater and increased evaporation due to climate change-induced reduced rainfalls. As illustrated in from 1950 to 2000, the Gambia's annual rainfall amounts have correspondingly decreased by about 30%. This decrease has become evident with the reduction in the length of the rainy season and also the amount of rainfall recorded in the month of August, particularly during the period 1968 to 1985, and in 2002. With the flat character of River Gambia and the low-lying features of the country, such registered drop in the amount of rainfall for the country could lead to a decrease in the river flow and therefore, induce more intrusion of saline-water from the ocean into the river. According to The Gambia estuary is vulnerable in the dry season, not only due to the advanced saline wedge, but also with the danger of hyper salinity due to high evaporation combined with very low freshwater inflows from upstream. The authors stated also that increasing vulnerability due to reducing rainfall-runoff is estimated at 30% reduction in rainfall over the past 30 years. Moreover, IPCC reports point out the fact that low-lying countries such as The Gambia are vulnerable to rising temperature (0.5 to 2.0°C by 2050) and reducing rainfall-runoff (-25% by 2050) [10]. It is therefore evident that reduced rainfall patterns may severely affect River Gambia water flow and also exacerbate saline-water intrusion further upstream where it has never occurred in the past. Data from the mid-1940s up to date reveal a decreasing trend in rainfall and length of the rainy season and an increase in temperatures [7]. Climate projections further show a considerable increase in the frequency of hot days and nights and a decrease in frequency of cold days and nights [18]. Agriculture and Natural Resources (ANR) sector has focused mainly on irrigation, (surface and tidal) obtained largely from freshwater resources from River Gambia, and mainly for rice production. Key constraints in swamp rice production relate to timely operations, access to swamp land, saline-water intrusion, and low input use [19].

Climate change-induced sea-level rise

Induced-greenhouse gases (GHG) by human activities are incriminated as predominant factors of climate change. They contribute to the rise in global temperature of the earth. Rising temperature expands the ocean's volume in two ways. The rise in temperature leads to the melting of mass volume of ice of the polar region and causes thermal expansion of the ocean's water; thus the increase in volume of ocean's water of the earth and rise in the sea level. Therefore, sea-level rise is one of the major contributing factors to saline-water intrusion in The Gambia. The countries lowest point is at sea level and the highest point is 53 m hence putting area such as the capital Banjul at significant risk from sea level rise [16].

In literature, many studies conducted globally, especially in countries open to the sea, have highlighted critical issues related to saline-water intrusion. According to a 50 cm rise in the Mediterranean Sea-level will cause additional intrusion of 9.0 km in the Nile Delta aquifer [20]. The same rise in water level in the Bay of Bengal will cause an additional intrusion of 0.4 km. For The Gambia's case, accelerated rates of sea-level rise could cause inundation of low-lying land, saline-water intrusion into groundwater and streams, increased extent and severity of storm flooding, and coastal erosion [21]. Sea-level rise will have a major impact on The Gambia because so much of the economic activities are located in the coastal zone [22]. Therefore, sea-level rise is expected to exacerbate salinization in these areas, including lowlands adjacent to the mangroves systems, near the swampy areas used for rice farming.

Impacts of Saline-Water Intrusion on Livelihood of Gambians:

Water resources

River Gambia is a major waterway and tourist attraction disposing of floodplains, riverbanks and wetlands which are important habitats for wildlife and play an important role in local livelihood strategies. Previous studies have not yet established the extent of saline-water intrusion and its impacts on River Gambia. However, it is widely known that the extent of saline-water intrusion in River Gambia is mainly governed by the balance of outward advective transport by freshwater and inward dispersive salt transport from Atlantic side, extended with the rainfall rate, which accounts for the local rainfall and evaporation [17]. Few studies on water quality have revealed an increase in the salinity of the river. A recent study by has revealed an alarming increase in values of river water conductivity during the dry season [23]. Though the study did not give the status of the river in the wet season, these results confirmed that saline-water intrusion affects the water quality of the river. This could result in disturbance of the river ecological balance including fisheries with all micro-ecosystems depending on the river. This raises the problem of constant monitoring of the river water salinity throughout the year. Such a lack of data on salinity over years may not help in deepening the understanding of

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the effects of saline-water on the river and its extent. Consequently, efforts and measures of limiting or controlling the saline-water intrusion are likely to be in vain.

Soil quality

Most of the soils in the rice-growing areas in The Gambia have become more saline over the past years, and therefore reducing the cultivable lands. A lot of lands that were affected in mid-1900s have been abandoned by rice farmers. They are no longer utilized for crop production, mostly due to increased soil salinity. Because of the salinity, tidal swamps, which are located on the margins of the river, are divided into perennial freshwater tidal swamps and seasonally saline tidal swamps. Increased soil salinity limits growth of crops and affects overall crop production, and also makes the soil unsuitable for many potential crops [24]. The soils of the lowlands are flat, fine textured and poorly drained. In the lower parts of the river, potentially acid sulphate soils occur, which can become acid sulphate soils unless waterlogging is prevented by drainage [2]. Rice cultures which most of the farmers cultivate are located in lower river region and thus, facing saline-water intrusion issues on the lowlands. This disrupts rice growth and decreases its production, if saline-water intrusion is not well managed.

Agricultural production

Agricultural farming in The Gambia is mostly characterized by subsistence rain-fed production, depending on the distribution and amount of rainfall. Increased salinity is having detrimental effects on crops by limiting the productivity of agricultural crops. Generally, most crops are sensitive to salinity caused by high concentration of salts in the water and the soil.

A high salt content of irrigation water can affect crops. This is an on-going concern for The Gambia due to the tidal insurgence which reaches approximately 240 km upriver. Rice crops, grown in the upper reaches of River Gambia cannot grow in areas reached by saline water [25]. The high salt content in the farming environment increases cost of production of poor farmers. Therefore, farmers are obliged to make more investments to control the salinity through construction of anti-salt edifices which are costly. Moreover, there are other serious impacts of salinity on people's livelihoods and stability of communities. According to before 1986, the year where a decrease in rice production begun to be felt, rice hectarage production had increased form 20 hectares in 1980 to 170 hectares by 1985. Therefore, due to terribly low flows in 1986, hectarage in production in the lowest reaches of the middle zone had dropped to less than 20 hectares. According to rice accounts for 56% of the cultivated land in The Gambia. With rice being the staple food in The Gambia, it contributes to 25-35% of total cereal production. The saline-water intrusion tends to reduce the availability of land for rice cultivation by diminishing land fertility and suitability. Furthermore, it is established that there was an increased drop in harvests over the past years. In the lower reaches of the middle of River Gambia, there is an increased trend of saline concentration that makes rice production a marginal activity. Lower stream-flows from poor or erratic rainfall mean that the yields from swamp rice will decrease because of the advancement of more saline-water intrusion. From 2000-2010, total national area under rice cultivation is increasing whilst the production is declining particularly in the lowlands **(Figure 2)**. This could be partly attributed to the steady decline in rainfall, adverse growing conditions, limited resources available to farmers and lack of suitable rice varieties, increase salinization and poor water management of and control structures [7]. Decline in national rice production has significantly increased the dependency of rural population on imported rice, thus reducing their savings and net income. Income generated from other farming and off-season farm activities are inevitably used to procure imported rice.

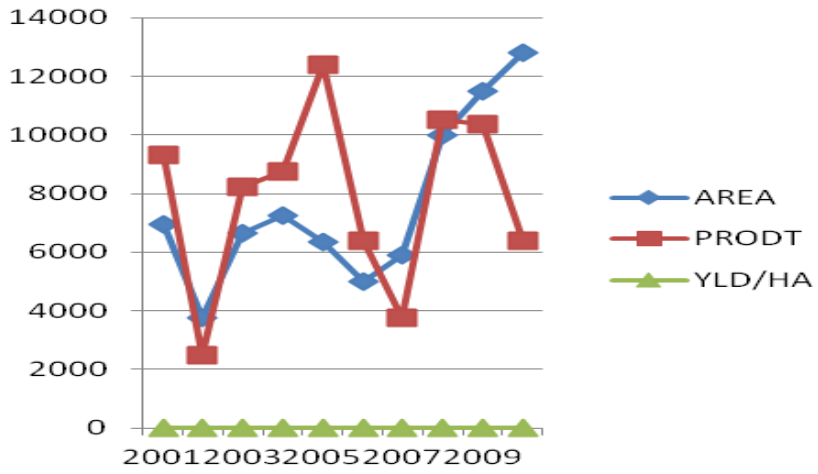

Figure 2. Productivity in lowland [25].

Note: AREA: lowlands under rice cultivation PRODT: National Rice Production

In addition, a 1 meter rise in sea level would inundate over 60% of current mangrove forests, 33% of swamp areas and 20% of rice growing areas.

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River Gambia and rice cultivation

Rice is one of the most important food crops in the world considering the area under cultivation and the number of people depending on it. Rice ranks second position after wheat in terms of area harvested, but in terms of importance as food crop, it provides more energy per hectare than any other cereal crop. Moreover, at average world yields, a hectare of rice could sustain 5.7 persons for a year compared to 5.3 for maize and 4.1 for wheat [26].

Since the 1980s, rice cultivation has wavered between 15,000 and 20,000 hectares while pump-irrigation involves only about 1,500 hectares of that amount in the permanently freshwater zone of River Gambia [27-30]. Riverine seasonal mangrove swamps of lowlands are very well valued for rice cultivation in The Gambia. Thus, lowland cultivation in the country sustains farming activities even in dry seasons. Knowledge of riverine swamps farming is women's domain. Women have a strong tradition of rice cultivation and a good but informal skills base [26].They have been involved in rice cultivation since the slave trade time and have adapted to lowlands specific micro environmental conditions. This is an important value to The Gambia well-known in the sub-region for its expertise of domestication of varieties of rice. An example is the West African rice (*Oryza glaberima*), domesticated in the region at least 3,000 years ago. Rice is the staple food in the Gambia with a per capita consumption of 117kg per annum [16]. The annual requirement stands at about 199,000 Million Tons out of which only 17% is produced locally and the deficit has to be imported. There is a long history of rice importation into The Gambia.

CONCLUSION AND RECOMMENDATION

Agriculture practitioners, especially lowland rice farmers, have a long history of rice cultivation in The Gambia. Past and current challenges registered as a result of saline-water intrusion into the lower middle reaches of River Gambia have significant negative impacts on rice cultivation. The incremental disappearance of freshwater swamps and soil salinization in lowland areas as a result of sea level rise is likely to impact negatively on rice production and the livelihood of women farmers. The decline trend of rainfalls associated with sea-level rise both from projected climate change increase the abandonment of rice fields in areas highly productive in the past. Consequently, national rice production has steadily decreased over the years. This led to a dependency on imports of rice to meet the national rice deficit. Externalities of food insecurity and volatile global market trends are more likely to happen. In the face of such unceasing increased trend of low rice production with all its associated negative impacts on livelihoods of Gambians, efficient measures need to be taken. The following is a list of recommendations to adapt or mitigate saline-water intrusion impacts on rice farms located in the lower middles reaches of River Gambia:

- A dam should be constructed at Sambangalou, several hundred kilometres upstream of the country. This is the most feasible alternative to limiting the saline-water from ocean to intrude inlands as regard to the cost-efficiency and little environmental impacts. This will help to push back the saline wedge up to 100 km downstream of its habitual location. It will also yield additional freshwater flows during the dry season, and enabling therefore, increase of irrigated arable land for agriculture.
- Activities of regular monitoring of the salinity of the river during the year should be carried out.
- Construction of embankments/dikes to protect sensitive areas.
- Changes in pumping policies of fully penetrating aquifers along the coastline in order to reduce the risk of saline intrusion.
- Increase water column in wells due to decrease in recharge.
- Licensing and permits for withdrawal of river water for irrigation.
- Development and provision of subsidized saline tolerant crops, especially saline tolerant rice cultivars.
- Increase training support for rice farmers on best cultivation and land use practices.

As further areas of investigation on saline-water intrusion into River Gambia, an assessment of rice farmers' adaptive strategies to saline-water water intrusion in the country could be helpful in yielding more vital information on the phenomenon and to provide alternatives to sustainably solve or adapt efficiently to the intrusion of saline-water in the country.

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