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Availability and Co-Substrate Potential of *Typha latifolia* for Biogas Production in Funtua, Katsina State, Nigeria

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ABSTRACT: In order to reduce global warming through fossil fuel utilization, biogas production from biodegradable biomass seems a sustainable alternative. This study evaluated the availability and co-substrate potential of *T. latifolia* for biogas production in Funtua, Katsina State Nigeria. A purposive sampling technique was used in selecting the wards that were used for this study. A 1204 metres transect was used for 32 quadrats; 19 of these were laid on the 953m contiguous land area at intervals of 50m; 9 quadrats covered 450m, 5 quadrats were on 250m, 3 on 153m, and 2 on 100m. The remaining 13 transects were laid on the 251m un-contiguous patches. Coordinates of various potentials sites were recorded using Global positioning system. There were an average of 27 *T. latifolia* stands per m^2. A total of 32,388 of *T. latifolia* stands were recorded in the study area; Dukke ward (23,968), Makera (8,205) and Maska 216. *T. latifolia* is available in lqrge quantities, and a potential co substrate in anaerobic digestion for biogas production in Funtua. It is recommended that the study should be replicated in time later to establish a trend of the *T. latifolia* species in terms of population.

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Energy crisis and climate change are key issues of concern. Global energy demand is set to rise by 4.5% in 2021 after a fall of 4% resulted by Covid-19 pandemic in 2020. Coal demand is predicted to rise by 60% more than all renewables combined, reinforcing a rise in emissions of greenhouse gases of almost 5%. Oil demand is set to rise by 6%, Natural gas by 3.2%, while electricity is expected to increase by 4.5% in 2021. Coal demand alone is expected to put global demand more than 1% above 2019 levels. This expected increase would reverse 80% of the drop in 2020, with emissions ending up just 1.2% below 2019 emissions levels (IEA, 2021). As the demand for energy continues to increase, the global average temperature also increases. According to researches' prediction, global average temperature is predicted to increase by 1.8– 6.4°C by the year 2100 and continue to rise long after that (Dow and Downing, 2006; Intergovernmental Panel on Climate Change - IPCC, 2014; Chatterjee and Saha, 2018). Global warming as the result of climate change is now more certain than ever. It is now broadly accepted that it is caused by the rapidly increasing concentrations of greenhouse gases in the atmosphere, which is emitted mainly by the combustion of fossil fuels, containing carbon such as coal, oil, and natural gas (IPCC, 2007; Jaynes, 2010; Nwankwoala, 2015; Eduok *et al*., 2018; Matthew *et al*., 2018). It is also noted that the world population is predicted to reach 8.6 billion in 2030, 9.8 billion in 2050, and 11.2 billion in 2100 (United Nations –UN, 2017; Allam, 2019). Consequently, the energy demand will increase which must be provided with energy and materials for survival (Sunarso *et al*,

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2012). To arrest the looming predicament of hydrocarbon-base-fuels that result to global warming, climate change, deforestation, and loss of biodiversity as well as negative impact on human health, research into alternative sources of energy that are environmentally friendly becomes paramount. Among which biogas has been identified as a viable option. Moreover, to maximize production, grass is considered a more suitable feedstock; since it's availability is not limited to seasonal change. Energy crops and crops residues represent an important source of biomass that can serve as a substrate for biogas production. According to Martínez-Gutiérrez (2018) non-edible plants such as grass and aquatic plants are suitable substrates for biogas production. Gerin *et al* (2008) reported that, methane from grass has shown to be suitable for vehicle fuel. While according Abu-Dahrich *et al* (2011) asserted methane content of about 70‒80 % from grass silage stream. It is on this note that Grosshans (2014) showeded that cattail (Typha) biomass has proved to be a viable, renewable and sustainable feedstock, or "ecological biomass", for bioenergy production. *Typha latifolia* (bulrush, cattail, reed, reedmace, Kachalla) is a monocotyledonous flowering plant that has thrived temperate regions and higher altitudes. It is very widespread and found in temperate northern hemisphere, but was introduced to Australia. They are dispersed by wind, but can spread through the rhizomes. It colonises wetlands and are dominant competitors in such areas, as they develop dense canopy (Keddy, 2010). They are now found in tropical countries. They have been regarded as invasive in many places. The Typha family, represented worldwide by genus Typha and the weed is a perennial aquatic herb with cosmopolitan distribution in freshwater habitat, it is an erect perennial and can grow two or more meters in height (Bender, 2018). The Typha family has higher growth rate than any other aquatic plant and the family, is characterized by having rhizomes, extensive fleshy stems, tall, leaf blades, strap-like, stifle, spiraling in top half, sheathed together at base flattened (Yakubu *et al*., 2015). The weed is inflorescence spike like, densely packed with tiny male flowers in top cluster, and female flowers in bottom cluster. The fruits are hairy and about 5-8mm long (Yerima, 2016). The Typha has been implicated for reducing agricultural activities, fish in wetlands, and impeded navigation in water ways (Abdullahi, 2015; Boyd, 1971; Mohammed, 2016: Kutama *et al*., 2016). The plant can be used for food, medicines, biomass products (baskets, hats, mats, mattress, pillows, thatch for roofs and fences, biofuel). It can be used for phytoremediation. Aquatic macrophytes such as *T. latifolia* present in dense biomass have the ability to influence plant structure and distribution and also, extensive litter deposition by *T. latifolia* also buried mineralized substrates necessary for many native plants to germinate (Lynn, 2005). This may strongly affect plant community composition by inhibiting their establishments that may lead to habitat homogenization (Charles and Dukes, 2007). Consequently, this may decline the abundance of economically valuable species, in particular those used for food, fodder and/or medicinal plants and loss of local genetic resources thus, genetic diversity (Lynn, 2005). More so, primary production may increase or decrease if plant invader leads to a shift in the major vegetation type of a wetlands area (Ringim *et al*., 2017). However, most invasive plants increase net primary productivity as in the case with giant reed (Arundo donax), and other Typha spp. such as Phragmites in marshes (Ehrenfeld, 2003). In Tukwikwi flood area of the Hadejia-Nguru wetland, about 70 % of the wetland was covered by both Typha and Daura grasses (Yakubu, 2015). Impacts of biological invasions can be found on all levels of the ecological organization that is; individuals, populations, species, communities and ecosystem. Specifically, dramatic changes can occur when introduced species function as keystone species or ecosystem engineers thus, affecting the functional diversity and food web structure of communities and ecosystems (van der Velde *et al*., 2006). On the Marma channel and Nguru lake (a section of Hadejia-Nguru wetlands) for an example, where *T. latifolia* invasion is more severe with over 35,000 hectares of potential farming and grazing lands have been taken over by the Typha grass., conversely, it has also contributed to the desiccation of Burum Gana channel, where about 60% of dry season irrigation farms have been hindered. The studies by (Yerima, 2016), revealed that the economy and ecology of the people living in Hadejia-Nguru wetland is threatened with proliferation of an invasive *T. latifolia* which is colonizing most irrigated lands and the People in the area are currently living within the poverty scale. Because, the presence of the weed in the area has markedly interfered with the utilization of water and land resources, this weed inhibits agricultural activities which are the primary occupation of the inhabitants. Consequently, there is loss of farm lands, fishes, hunting as well as grazing lands (Yerima, 2016). In the same vein, results of the study conducted by (Babagana *et al*., 2018a) revealed that hunting has reduced by 66.7% and 80% of the main canal and other water distributaries channels have been overtaken by *T. latifolia* thereby blocking the free flow of water into the irrigation fields (Babagana *et al*., 2018b). According to Kutama *et al*., (2016), large biomass of *T. latifolia* has been responsible for the decline in fish catch, diversity, as well as size and abundance. Presumably, the *T. latifolia* vegetation provide a hiding ground for many fish species with African arowana (Heterotis niloticus) being a typical example. Channel blockages caused by *T. latifolia* have reduced flooding in many parts of the wetlands that lead to decrease in fish abundance (Ringim *et al*., 2016). *T. latifolia* has become a nuisance affecting social and economic well-being of the people that depend solely on the wetland for their livelihood. *T. latifolia* decreases income, hence, increases poverty level of communities around the wetlands and also often lead to conflicts among farmers (Babagana *et al*., 2018a). The invasive plant has colonized many large farms, grazing lands, and river channel thereby making life miserable for the inhabitants through interference with their utilization of water and land resources. This led to migration of the inhabitants from one area to another causing conflict over resource use, and increased poverty (Sulaiman *et al*., 2016). Transportation, hunting and tourists guide were successful economic activities engaged by local communities along the Nguru wetlands. The menace of *T. latifolia* invasion in recent years had badly affected these professions, especially transportation by canoes. Equally, (Babagana *et al*., 2018b; Kutama *et al* 2016) reported that Maikintari flood along Hadejia-Nguru road, the wetland was an entirely different thing as it was 100% occupied or dominated by Typha grass. One could not see any water/wetland at a glance from or by the road side. *T. latifolia* has become a serious menace to several human activities in the Hadejia-Nguru wetland (Babagana *et al*., 2018b). *T. latifolia* harbours thieves and other criminals especially cattle rustlers and kidnappers (Haladu and Bello, 2014). According to Ringim *et al*. (2016) the impacts of *T. latifolia* on recreation and tourism, boating, swimming and diving activities are enormous. *T. latifolia* serves as host to the vectors of cholera, bilharzia (schistosomiasis), malaria and dysentery (Gabriel *et al*., 2016). The prevalence of Mosquitoes and related diseases are on the increase due to Typha takeover of the wetland and according to (Gabriel *et al*., 2016). Malaria was perhaps, the most prevalent disease affecting the communities dwelling around Hadejia Nguru wetland because it was ideal for mosquitoes breeding as long as the area was not completely deoxygenated by aquatic plants and the possible explanation for this is that *T. latifolia* provides a good habitat for the laying and hatching of mosquito eggs as it shelters it against high isolation and wind. However, it has many ecological and economic values. It is a rhizomatous aquatic or semi-aquatic herbaceous perennial (Stace, 2010). *T. latifolia* is useful for controlling erosion, and is good for phytoremediation of polluted waters, especially waste waters. They have been implicated as blocking water flow and navigation in rivers. It has medicinal uses. The root stock is astringent and diuretic, useful in treating measles, dysentery, and gonorrhoea. It has been used as source of food. It is used for transportation, animal feed, roof and mattress making. The sale of these products contributed significantly to the income of the producers. During the dry season, pastoralists used *T. latifolia* as animal feed and for the making of shelter. (Tessema *et al*., 2013). The leaves are used for the production of baskets, mats, and seats of chair. The leaves when treated can be used for making baskets, mats, or sandals (Nyerges, 2016). Hazra *et al*., (2015) reported the capacity of *T. latifolia* to accumulate iron and manganese in its root and shoot, from contaminated water bodies in Ranchi city, India. In wetlands that are taken over by Typha, they can be harvested for other uses such as enhancement of wildlife habitat enhancement, nutrient bioremediation, biofuel production, bioproduct generation such as construction materials, and use for boosting local economies (Bansal *et al*., 2019). The plant accumulates heavy metals and toxins and has been used in cleaning polluted waters. Ciria *et al*. (2005) showed that the macrophyte *T. latifolia* could be used in constructed wastewater treatment and as biomass for biofuel production for villages, thereby substituting conventional fossil fuels. *T. latifolia* is invasive grass that takes over many irrigated farm lands and water channel. It drains nutrients and other minerals required for growth of other farm plants using it roots. Previous studies conducted were mainly interested in different species of Typha, characteristics and its adaptation, variations in growth and reproduction, invasion and impact on agriculture as well as growth performance, such studies include Grace and Wetzel (1982), Bansal *et al*. (2019), Pincama *et al* (2020), Zhang *et al* (2020). Typha has been considered as a phytoremediator that could also be a biofuel plant considering its ability to grow prolifically in wetlands. It has also been used in constructed wetlands for wastewater treatment (Kaur *et al*., 2018). *T. latifolia* can be used as a feedstock for bioenergy production. The increase in oil prices, depletion in fossil fuel reserves, and the rise in greenhouse gas emissions from agriculture, especially livestock, fosters the need to consider the use of cattle dung for biogas production. This becomes more necessary in rural areas and developing economies where there is available cattle dung that could be used for biogas production at low costs. The presence of *T. latifolia* in wetlands around Funtua could be exploited as co-substrate to cattle dung for biogas production.

An understanding of distribution and population density of *T. latifolia* over space is important in this study because these constitute variables that determine the availability in a given geographic location (geographical potential). There are limited studies that quantifies *T. latifolia* and its actual potential as co-substrate to cattle dung for use as energy source in Funtua. This study assessed the available quantity of *T. latifolia* and its biogas production enhancement when used as a co-substrate with cattle dung in anaerobic digestion. The study looked at potential as availability of the substrate used as well as their ability to produce gas. It also determined the soil pH and rainfall regime in the area.

MATERIAL AND METHODS

Study area and scope: The study was conducted in some wetland areas in Funtua, Katsina State, Northern Nigeria. Funtua is located about 150 km southwest of Katsina town (Fig. 1). It is on $7^0 43'$ – $7^0 44'$ E and 11^0 50' - 11^0 52' N. Funtua falls within the tropical savanna climate with distinctive wet and dry seasons. Average total rainfall is about 750-800mm per annum with rainfall duration of 5-6 months. The climate is hot and dry for most of the year, with a maximum daily temperature of about 1000F (38^0C) and minimum of about 550F (22^0C) (Adamu, 2000). Funtua is therefore a suitable location for the growth of T. latifolia. The relief of Funtua falls under the high plains of Hausa highlands with a gently rolling terrain, while the streams generally have a north-south alignment. Funtua has very few rivers and lakes, many of those present are either intermittent/seasonal or reduced drastically in volume during the prolonged dry season. However, it appears to be a hydrographically active region because of the available water resources. Most rivers take their sources from the basement complex plains and pediments in the center of the State Thus, that the relief of the study area which is a low land and it hydrographic nature aids the growth of T. latifolia. The scope of the study was limited to the geospatial distribution, and population density of *T. latifolia* in three Wards (Dukke, Makera and Maska) in Funtua Local Government Area (LGA).

Reconnaissance Survey: A reconnaissance survey was conducted in the 11 wards of Funtua LGA, viz: Dandutse, Dukke, Goya, Maigamji, Makera, Maska, Nasarawa, Sabon-Gari, Tudun, Ungwan Ibrahim, and Ungwan Musa. This was to assess the hydromorphic nature of the soils and identify wetlands such as dams, rivers, streams, and other water channels, which are typical areas *T. latifolia* could be found. Three of these Wards: Dukke, Makera and Maska met these requirements. The survey also served as guide in the choice of the sample size, sample plots, and sampling technique used in the study.

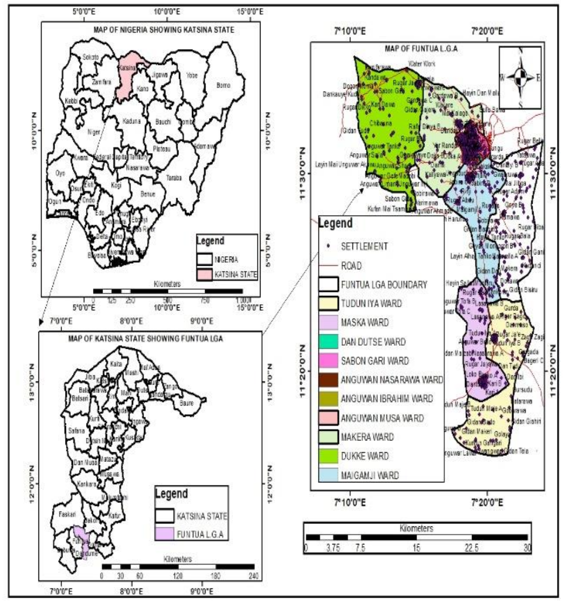

Fig. 1: Map of study area
Source: OpenStreetMap Database modified with Arc GIS 10.7

Sampling Technique: Purposive sampling technique was used in sampling the three Wards Dukke, Makera and Maska that had T. latifolia. The quadrat sampling method was used to determine the population density of *T. latifolia* (expressed as number of typha stands per m^2). The number of quadrats used per Ward were based on the number of patches or meters covered by the *T. latifolia* in a Wards.

Data Collection: Primary and secondary sources of data were used for the study. The primary data were the population density of T. latifolia, and pH of the soil where the grass was found. Quadrat frame of 3 x 3 m dimension, and digital pH meter were respectively used for the determination of the population density and water pH. The secondary data were the spatial distribution of *T. latifolia* and rainfall. Spatial distribution of the plant was obtained through the use of Global positioning system (GPS) of the areas the plants where sampled, and Arc GIS 10.7. The rainfall data was obtained from Katsina State Agricultural Development Authority (KTARDA).

The sample size and sampling technique involved the use of transect on which quadrat was placed on 50 m intervals as described by Goodall *et al*. (2006). A total of 32 quadrats (3 x 3) were used as sample size on 1204 metres transects. Of these, 19 of the quadrats were laid out on the 953 m contiguous land area with interval of 50m apart in this order: 9 were laid on 450 m; 5 on 250 m; 3 on 153 m; and 2 on 100m. The remaining 13 transects were laid on 251m un-contiguous patches: the quadrat was laid on each of the 13 patches.

To increase the efficiency in enumerating the T. latifolia, the minimum plot sizes suggested by Mfitumukiza (2004) of 5 x 5 m was modified in this study to 3 x 3 m, which was further partitioned to 1 x 1 m due to the peculiarity of some patches.

Data Analysis: The vector shapefile of the study area was obtained from OpenStreetMap Database. The locations of *T. latifolia* were obtained by the use of global positioning system were transformed into geographic coordinates, imported into a GIS environment and a population density map was produced. The population of T. latifolia, and rainfall were analysed using descriptive statistics.

RESULTS AND DISCUSSION

Population density of T. latifolia in the Study Area: Table 1 showed the population density of *T. latifolia* in the three Wards in Funtua LGA. An average of 27 number of *T. latifolia* was recorded in every m^2 In Dukke Ward, 23,968 stands of *T. latifolia* were recorded. This was followed by Makera with 8,205 stands, and Maska which had only 216. A total of 32,388 stands of *T. latifolia* were recorded in the study area.

Table 1: Population density of *T. latifolia* in the study areas

Ward	Population (stands)	Total area enumerated (m^2)	Density
Dukke	24074	891	Densely
Makera	8,235	305	Moderate
Maska	216	8	Sparsely
Total	32,388	1204	

The geospatial density of *T. latifolia* in the three Wards is shown on Figs. 2 and 3. The plant occurred in clusters, and were very close to each other in Dukke Ward. The clusters were reduced in Makera, while in Maska Ward, they were sparsely distributed. This may likely be attributed to the fertility of the soils that varied in the different locations as asserted by Adamu *et al*. (2013).

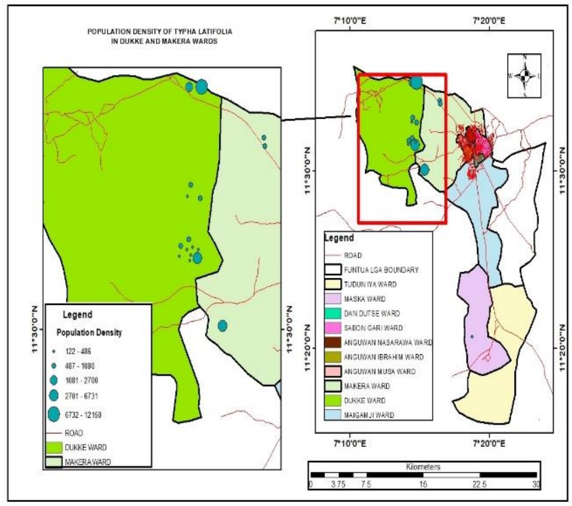

Fig. 2: Population density of *T. latifolia* in Dukke and Makera Wards

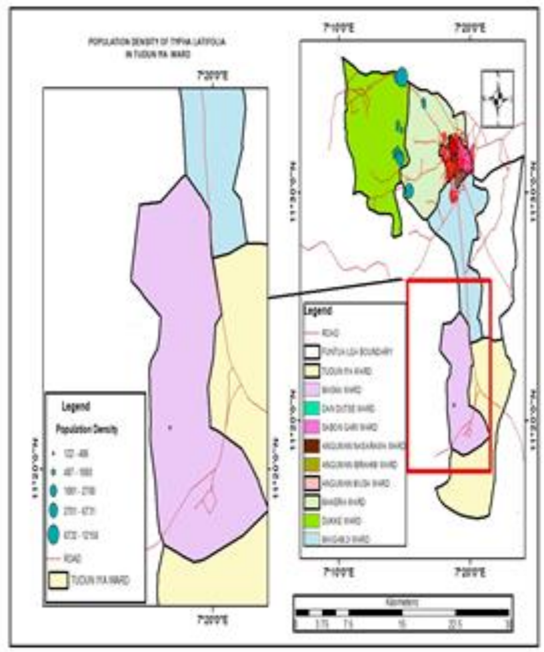

Fig. 3: Population density of *T. latifolia* in Maska Ward.
Source: OpenStreetMap Database and Modified with Arc GIS 10.7

Spatial distribution of T. latifolia in the Study Area: Fig. 4 showed the spatial distribution of *T. latifolia* availability. There were 18 patches of *T. latifolia* in the three Wards, of which 77.8% were in Dukke, 16.7 % were in Makera, while only 5.6% was in Maska It is clear that the distribution of plant in the study area was not even. The concentration of *T. latifolia* was high in Dukke Ward, moderate in Makera Ward and sparse in Maska Ward. The locations where *T. latifolia* were found were irrigated lands, water channels, streams and dams. The high concentration of *T. latifolia* in Dukke Ward could be attributed to the presence of Mairua Dam, streams and water channels followed by the hydromorphic nature of the soil. Abdullahi (2015); Babagana *et al*. (2018b) revealed that *T. latifolia* survives in a wet environment or an area with plentiful rainfall, and also fits the description of Bansal *et al* (2019) that Typha are obligate wetlands, meaning they cannot survive in non-wetland habitat. This attracts irrigation farming while the supply of organic manure for the purpose of irrigation renders it suitable for the growth of *T. latifolia* (Sabo *et al*., 2016). Makera had Gwaigwaye Dam as well as water channels that empty into the Dam. Additionally, the nature of the soil was observed to support irrigation activities. While Nasarawa in Maska, by the fringes of the Maska Dam was recorded to have only 5.6% of *T. latifolia* availability, which might be attributed to the nature of the soil and also irrigation farming that began recently. Therefore, the required nutrients that attract the growth of *T. latifolia* may be absent. Fig. 4 showed the spatial distribution of *T. latifolia* availability in the study areas. It is clear that the distribution of plant in the study area was not even. The concentration of *T. latifolia* was high in n Dukke Ward, moderate in Makera Ward and sparse in Maska Ward. The locations where *T. latifolia* were found were irrigated lands, water channels, streams and dams.

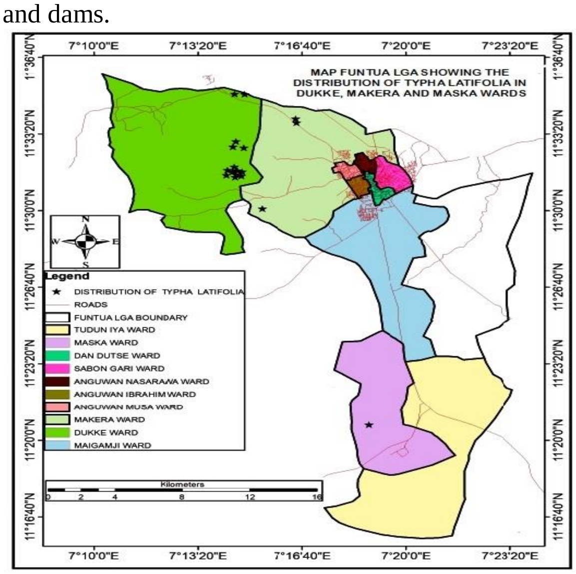

Fig. 4: Spatial Distribution of *T. latifolia* in Dukee, Makera, and Maska Wards
Source: OpenStreetMap Database and Modified with Arc GIS 10.7

In Gwaigwaye, Makera Ward, the Typha was noted to have invaded an entire stream which was initially used for irrigation purpose. It was also observed that some part of Mairua Dam in Dukke Ward was lost to siltation as a result of *T. latifolia* invasion. A similar situation was observed on the stream in Mai Rukuntu, Dukke Ward. This invasion had altered the hydrologic variability of the Dam as well as the streams. Sabo *et al*., (2016) and Bansal *et al*., (2019) reported that *T. latifolia* invasion into natural wetlands are often associated with hydrologic alterations. This study has shown the potential of *T. latifolia* in terms of availability. Yang *et al* (2018) also established availability of food wastes in China as potential in biogas production, it is therefore necessary to know the substrates potential in a given region (Karki *et al*., 2015). On potential for domestic biogas as household energy supply, Msibi, (2015) considers availability in term of quantity and accessibility to feedstock while resource potential was considered in the study as ability or capacity to yield biogas.

Environmental Conditions Favoring T. latiofolia Growth: The soil pH is an index of the hydrogen ion concentration (H+) in soil water. It is a measure of it's acidity or alkalinity. It is on a scale of 0–14, with a pH value of 7 as the midpoint (7)neutral; pH values below 7 represent progressively more acidic reactions, and pH values above 7 represent progressively more basic or alkaline reactions (Boyd *et al*., 2011). The values of pH were recorded at the range of 5.7, 6.5 to 6.9 at the three different locations (Mairua Dam, Makera stream and Maska Dam) and fall within the sustainable level for the growth of *T. latifolia* (Abdullahi, 2015). While the pH of *T. latifolia* in these locations were 6.6, 6.5 and 6.4 respectively, thus these fall within the suitable range for anaerobic digestion.

Rainfall: For 14 years (2007 – 2020), the average total rainfall received in Funtua was about 1384.5 mm and 195.1mm monthly with rainfall duration of 6-7 months. The month of August was observed to be with the highest rainfall amount with an average of 400.7 mm. There was little or no rain in November and December. February was observe having the least amount of rainfall with an average of 0.02 mm (Table 2).

This show that wet season in the study area is more favorable for the growth of *T. latifolia* as it survives in warm climate with high levels of humidity and rainfall (Abdullahi, 2016). This was in agreement with the finding of Yusuf & Muhammed (2011) that revealed that the highest amount of rainfall was recorded in the month of August.

According to Labaran and Idris (2016) evaporation is higher in the dry season and lower in the wet season. Thus the study area is suitable for the growth of T. latifolia

Table2: Mean monthly rainfall data

Month	Mean monthly rainfall (mm)	Years	Annual rainfall (mm)
January	0.75	2007	1002
February	0.02	2008	1087.3
March	2.55	2009	1334.8
April	31.69	2010	1658
May	151.59	2011	1158.5
June	185.11	2012	1338.2
July	245.66	2013	1417.1
August	400.66	2014	1521.3
September	291.92	2015	1392.2
October	73.81	2016	1454.6
November	0.1	2017	1654.6
December	0	2018	1805.3
		2019	1540.4
		2020	962.2
Overall mean monthly rainfall	**193.2 mm**	Mean annual rainfall	**1384.5**

Conclusion: The research has been successful in revealing vital information on the potential location with the availability of *T. latifolia* in Funtua, which includes Dukke, Makera and Maska Wards. The presence of water bodies, water channels aid the growth of T. latifolia. It is apparent that *T. latifolia* can survive in wetland areas with moderate rainfall. Thus, the climate of Funtua is favorable for the growth of T. latifolia. Conclusively, this shows that Funtua has the potential in terms of availability of *T. latifolia* for use as co-substrate in anaerobic digestion. We recommend that the study should be replicated in time later to establish a trend of the *T. latifolia* species in terms of population in the study area.

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