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# Spatial Traceability of Irrigation Sources for Urban Agricultural Hotspots in Ghana

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**ABSTRACT**

This paper examines the traceability of water sources and its distribution for irrigation in a spatial context for some selected vegetable production hotspots at the Sekondi-Takoradi Metropolis in Ghana. The need for such a study had been a global call by food safety organizations, Public health and Standard Authorities, and development planners in Government agencies. The objectives were, therefore, to conduct preliminary spatial traceability on sources and distribution of water for Irrigation. GPS receiver and complimentary Satellite imagery (orthophotos) served as primary data to delineate spatial attributes. The study revealed that human-generated wastewater from homes/settlements was the primary source of water used for Irrigation to augment rain-fed Agriculture for all the three (3) study areas. The proximity of other land use such as manufacturing/processing industries; whose effluents were discharged from their premises joined the same receiving open drain as that of the human-generated wastewater. Thus, the study identified interconnectedness to the central drainage systems from which vegetable crops were irrigated within the Metropolis. The study concludes that adopting Geographic Information Systems' (GIS) technique in development planning studies of major or minor scales could inform decision making for improving Agriculture infrastructure access in Ghana.



## 1.0 Introduction

Horticultural crops are exceptionally high water demanding and thus irrigated with water from other sources (Arora et al., 2008) to augment rain dependent farming. These sources and state of quality of water for the Irrigation have become the epicenter to vendors, development planners, Public Health, and the Standard Authorities as far as production hygiene and food safety are concerned (Abdul-Ganiyu et al., 2011). In this case, delineating irrigation water sources in a spatial context to outline locations, distribution, and state of quality as either freshwater or wastewater could invaluably be useful. This would allow the generation of spatial maps for traceability of irrigation water sources, especially for crop production in Ghana. Following these concerns, the Sekondi-Takoradi Metropolis is no exception when it comes to vegetable production under irrigation vis-à-vis the recent public outcry for an investigation of its irrigation water sources. Irrigation present contamination risks, and so all sources must be validated for safe use as it may impact food safety (Shinkfield, 2016). Groundwater, surface water, and human wastewater are commonly used for Irrigation (Steele and Odumeru, 2004). The desired attainment in diverting water from natural sources for irrigation purposes is to produce the maximum crops consistent with economic conditions (Israelsen, 1932). Local vegetable market share might be anticipated to dwindle to imported vegetable crops with belief that, imported vegetables were produced under safe and known irrigation conditions. Playán et al. (2007), stated that, traceability of water has become a major concern in irrigation districts; implying the ability to relate each unit of water by a district to a water-using activity. Hence, the source of water for Irrigation should be verified (Jones et al., 2014). In food safety management, irrigation water is questioned (Opara, 2003), by both commercial food product buyers and consumers because of possible contamination. Under a global concern raised, Drechsel et al. (2002) have highlighted that, the entry points being investigated include sources of irrigation water. In a like manner, the sources and quality of water used for irrigating vegetables in the Sekondi-Takoradi in Ghana have received grave criticism especially as public health implications were raised by commercial buyers and local vegetable consumers in the Metropolis. According to Keraita et al. (2003), Urban and Peri-urban farmers in places like Kumasi in the Ashanti Region of Ghana have been using stream water and shallow wells sources for Irrigation mainly in vegetable farming. However, it should be acknowledged that, the paucity of available spatial data produced as maps to delineate the locations and distribution of sources of water for irrigated farms under vegetable production had been a hindrance to achieving development planning. Subsequently, it is also believed that interconnected Landuse such as spillage from automobile workshops, and Car washing bay may influence sources and state water quality. This specific constraint is dominant in many parts of vegetable production areas in Ghana, especially, in the Urban and Peri-urban centers due to high competition of limited resources such as land and water. Spatial traceability in this sense is the assessment of the sources of water for Irrigation encompassing mass landscapes from above-ground

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vividly depicting the earth's surface. It is considered that spatial data generally define and describe data of an environment (Mitášová, 1996), and creating a meaningful representation of events, occurrences or processes (Leyk, 2008).

## 2.0 Materials and Methods

### 2.1 Study Area

Sekondi-Takoradi Metropolis is one of seventeen (17) districts in the Western Region with a land area of about 49.78 km at the south-eastern territory between latitudes 4°52′30″ N and 5°04′00″ N and longitudes 1°37′00″ W and 1°52′30″ W (MoFA, 2017; Fei-Baffoe et al. 2014). The Metropolis, known as twin-city (Sekondi and Takoradi), is Ghana's third-largest urban agglomeration located at 223 km west of the capital Accra (Owusu-Ansah, and Atta-Boateng, 2016). The urban area experiences a temperature of about 22°C and a bi-modal rainfall of about 1,380 mm occurring between March-July and August-November as major and minor seasons, respectively. The surface of the Metropolis is fairly watered (MoFA, 2017). Statistics indicate that there are about 83,879 farmers in the Metropolis, with an average farm size of about 2 acres (MoFA, 2017). From which most households in the Metropolis (79.6%) are involved in crop farming, about 75% are engaged as skilled Agricultural, Forestry, and Fishery workers out of the employed population (GSS, 2014; MoFA, 2017). Though the study was not particularly focused on the total land size under cultivation, however, it could be asserted that overall land-area of all the zones as outlined in Table. 1 and Fig. 1 were about sixty (60) acres (~ 24 ha). The markets of Takoradi, Sekondi townships and it's environ were the main retailers of the fresh vegetable produced and occasional supplies to the country's national capital, the Greater Accra Region. Examples of vegetables produced were: Cabbage, Cauliflower, Carrot, Spring Onion, Lettuce, cucumber, Corchorus spp 'Ayoyo,' and many others.

### 2.2 Methodology

#### 2.2.1 Data Collection and Processing

Geographic Information System (GIS) is the acquisition of data and derivative information about an object (Nwugha, et al., 2017). Therefore, GIS tool such as GPS receivers were used to collect data (tracks, waypoints, and polygons) from the selected vegetable production hotspots in the Sekondi-Takoradi Metropolis, namely; Takoradi Airforce Base premises, Cocoa Villa and Takoradi Technical University (On and Off-Campus areas) in line with the traceability of irrigation water sources objectives. According to Tamilenthi, (2011), Geographical Information System (GIS) technology is used to define watersheds, stream-networks, and order. An independent orthophoto was used and Google Earth Satellite imagery, which gave wider inferences and scope, particularly with the ability to switch between time zones, were acquired and processed with data captured by GPS receiver for validation. Vegetable farms were digitized as polygons, drainage systems as lines, and zones as points. Loidl et al. (2016) asserted that, in a spatial domain, point data, Track/line features, and polygons are essential. Imageries were geo-referenced using Q-GIS application and further processed with Arc-GIS application for the spatial production of overall maps (Fozoon et al., 2012). Landuse special features with proximity were captured as coordinate and transcribed in field notepad for references and description purposes facilitated by a digital camera. GIS is a capable environment for the capturing, management, analysis, and visualization of spatial data as well as allowing for an integration of various data sources into a scalable, dynamic and adaptable geospatial framework (Loidl et al., 2016). Ultimately, the physical components of a landscape could be represented digitally, making complex analysis a relatively simple task (Graham, 2008). Data structure used in Geographic Information Systems (GIS) can be seen as a model of spatial data (Goodchild, 1987).

## 3.0 Results and Discussion

Polygon creation and sources of water and distribution for traceability, zoning of hotspot vegetable fields was done to simplify visibility and for more accessible map's readability (see Table 1 below).

**Table 1. Coordinates of Various Hotspot Vegetable Fields in Zonal Category, Sekondi- Takoradi Metropolitan Assembly (STMA)**

| Study Areas | Latitude (N) | Longitude (W) |
|---|---|---|
| Airforce Base (Zone 'A') | 4°54'11.83" | 1°46'25.00" |
| Takoradi Technical University | | |
| 1) Zone 'B' 1 | 4°54'33.70" | 1°45'29.03" |
| 2) Zone 'B' 2 | 4°54'30.93" | 1°45'13.63" |
| 3) Zone 'B' 3 | 4°54'42.03" | 1°45'12.38" |
| Cocoa Villa | | |
| 1) Zone 'C' 1 | 4°54'51.95" | 1°45'14.44" |
| 2) Zone 'C' 2 | 4°54'59.50" | 1°45'14.43" |
| 3) Zone 'C' 3 | 4°54'58.81" | 1°45'14.27" |
| 4) Zone 'C' 4 | 4°55'11.29" | 1°45'14.68" |

Source: Field Survey, 2017

### 3.1 Traceability of Irrigation Sources: Overview Map

The specific study areas are Takoradi Airforce Base premises, Cocoa villa, and Takoradi Technical University premises. These three (3) areas were considered hotspots of vegetable production in the Sekondi-Takoradi Metropolis; and are known for the vast quantities of vegetables supplied to the market.

The spatial traceability of irrigation sources of all the zones (A, B, and C) labeled as farms on the map, as shown in Fig. 1 was marked as mid-point with coordinates. This was done to trace all incoming source of water used in connection with all outgoing outlets that passes through the vegetable field. The study outcome revealed that all the incoming water sources (running water) were directly from neighboring human settlements; thus, the source of the water distribution was wastewater, which further interconnects from different smaller open drainage (as indicated in Fig. 1 in blue line). It is worth mentioning that the farmlands had minor drainage lines/gutters artificially carved by farmers to meander through their vegetable fields for ease of access to use, even though the spatial maps, as shown in Fig. 1, 2, 3, and 4 only delineated the major drainage lines. It was reported in the literature that, most vegetable fields are cultivated near open stormwater gutters and urban streams which are full of wastewater for easy access to irrigate (Keraita et al., 2003), with the large proportion of users being resource-poor farmers (Abagale et al., 2013). This is because farmers have huge problems finding in and around the cities unpolluted water sources for irrigating open-space vegetable farms (Obuobie et al., 2006). The running wastewater passing through all the study areas (zones) used for Irrigation joined several external main open drains adjoined to wetlands and finally to the sea. As shown in Fig. 1.

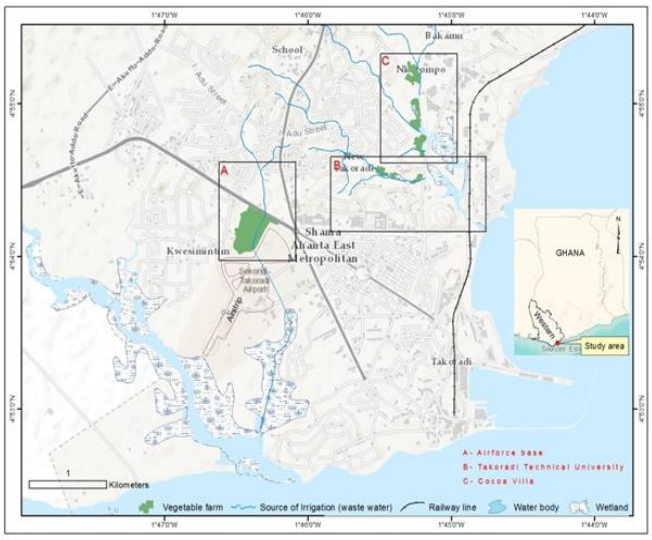


**Figure 1. Overview of Study Area Zones (Showing Irrigation Water Sources and Quality Used for Vegetable Production)**

### 3.2 Traceability of Irrigation Sources: Takoradi Airforce Base (Zone 'A')

On account of historical feature within Google Earth satellite imagery, there used to be an automobile industrial hub with its activities occupying an estimated land area of ~7 ha close to the study area (Zone A) where all sorts of vehicular maintenance were arraigned. Hence, an undeniable account of the massive oil spill and many other liquid waste materials could be implied to be discharged from such operations and, thus, percolates into the open drainage system shared by the Takoradi Airforce Base farmers where the vegetable production was undertaken. The study result revealed further that the discharge from the industrial activities drained into the same source of water used by the farmers in the vegetable production water used for Irrigation along a distance of about 350 meters and north in the direction of the study area (Zone A). Until 2013, the Sekondi-Takoradi Metropolitan Assembly acting on behalf of the Government re-located the entire industrial activities, and therefore between 2014 till as of 2017 during which the studies were conducted, such industrial actions did not impact the water source used for the vegetable crop irrigation. According to a comment by one of the farmers on the Takoradi Airforce Base Premises, "the vegetable production at Airforce Base Premises has long-standing history accounting to about four (4) decades". The total land area under production could be safely said to be one of the largest amalgamated vegetable fields in the entire western region. The source of Irrigation for the production was traced from a human settlement generating wastewater, which joins a wetland and finally to the sea at an estimated overall distance of ~3.5km, as shown in Fig 2. The wastewater was discovered to be the only supplementary means to rain-fed, especially during the dry season. At the Airforce Base landscape, the farmers had innovatively created smaller dug-out or created artificial ponds to collecting/impounding the flowing wastewater as storage mechanism. Watering cans were afterward used to fetch the impounded wastewater for manual Irrigation. This mode of Irrigation is confirmed by Keraita et al. (2003) that, watering cans are the most common means of Irrigation in the urban area and only a few farmers use motorized pumps/hoses. The study also revealed proximity of two (2) public cemeteries adjacent to the vegetable production field (shaded in yellow in Fig. 2); this feature had raised other concerns by the general public aside from the wastewater used in Irrigation at the study area. Contrariwise, these are limited to alternative irrigation facilities to be constructed.

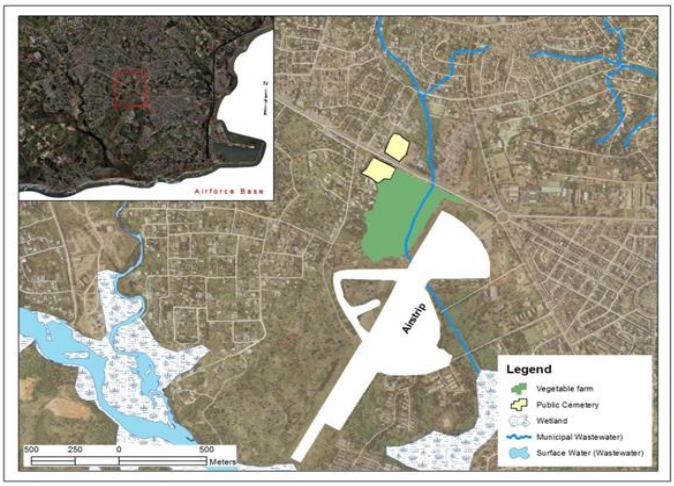


**Figure 2. Zone 'A' (Water Sources, Quality and near Land use around the Vegetable Production Catchment)**

### 3.3 Traceability of Irrigation Sources: Takoradi Technical University (Zone B)

The resultant outcome from the spatial traceability for Takoradi Technical University premises was not much different relative to the zone 'A', except that no industrial activities were noticed to influence the water used for Irrigation. This implied that the sources and distribution of water for the Irrigation at the vegetable production fields were likewise originating from human-generated wastewater from settlements, as shown in Fig. 3. Albeit the study did not identify any active Landuse as acknowledged in Fig. 2 and 4 as mentioned earlier, a substantial amount of impounded surface wastewater found at this study area (Zone B) owed to the fact that the topography of the general study area was mountainous. However, due to this topographic characteristic and by virtue of the valley bottom nature of this study area specifically, most of the human generating wastewater overflowing from these mountainous settlements became impounded, as shown in Fig. 3. This phenomenon further allowed a continuous flow of the human-generated wastewater to further join a larger wetland and finally to the sea at a cumulative distance of about ~2.5km. To the advantage of farmers on around that neighborhood, the wastewater from upstream was tapped for Irrigation to supplement rain-fed vegetable production, especially in the dry season.

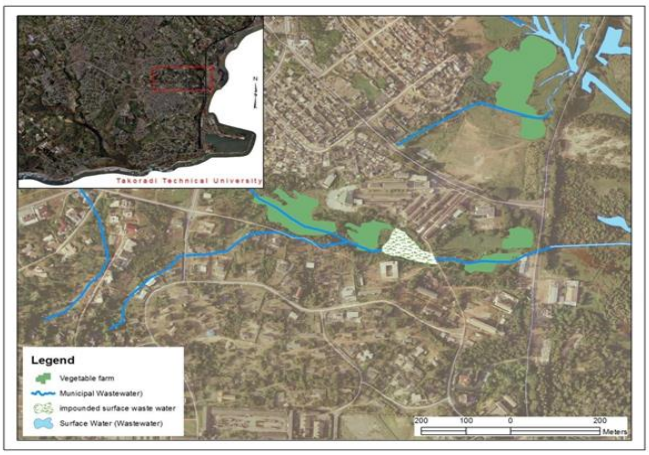


**Figure 3. Zone 'B' (Water Sources, Quality and near Land-use around the Vegetable Production Catchment)**

### 3.4 Traceability of Irrigation Sources: Cocoa Villa (Zone C)

The cocoa villa study area, by contrast to the previous two (Zone A & B) vegetable production hotspots correspondingly, revealed the same source of water for Irrigation as human generating wastewater from municipal settlement nearby. This generated human wastewater interconnects with liquid-waste discharge from adjoining industrial activities (as shown in Fig. 4 with blue line). The study also identified that the wastewater was distributed lengthwise in a culvert and non-culvert open drain designed to join a wetland and finally to the sea at an estimated distance of about ~2.8km. However, vegetable producers (farmers) located in the area discover it as a gain because of the water availability despite the unfitness to use for crop irrigation. An evident explanation of use by these farmers could be ascribed as supplementary to rain-fed agriculture, especially in the dry season. Also, it could be inferred that various kinds of pesticide residues as a result of fumigation activities at nearby warehouses could be present in the effluents. The effluents from the industrial premises are channeled into the open drains as further into receiving water bodies (wetland). Therefore, the use of this source of water for vegetable irrigation at Cocoa Villa could suggest contamination. As noted by literature, irrigation water may contain many trace chemicals (Zheng et al., 2010), which may be harmful to human health.

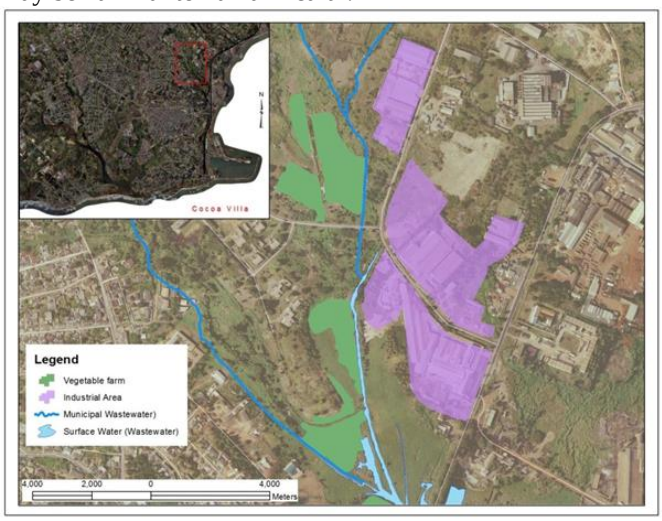


**Figure 4. Zone 'C' (Water Sources, Quality and near Land-use around the Vegetable Production Catchment)**

## 4.0 Conclusion

The study concludes that human generating wastewater was the most relied source irrigation with consideration to all the three (3) specific vegetable production hotspots in the Sekondi-Takoradi Metropolis most due to dry season farming. Land uses in proximity, such as industrial areas, tend to influence wastewater generation. Each of the study areas (Zone A, B, and C) had fairly different surrounding Landuse activities aside human-generated wastewater, leading to how the water distributions were influenced and ultimately the interconnected of these water (discharge) joining wetlands and then finally to the sea. The study ascribes the farmers' dependence on the wastewater use as sources of Irrigation to be due to the supplementary role it plays to rain-fed Agriculture. Subject to the findings of this study, it could be concluded on account that there are several apparent advantages in the use of Geographic Information System's tools for data collection and processing, traceability of features, analysis and optimizations for irrigation studies. In perspective, the spatial results obtained in the study defined most of the paucities of details that could be visually incapable of grasping, giving the exclusive and explicit details from orthophotos and satellite imagery under consideration. The study focuses on spatial traceability using GIS was useful in delineating the where-from and where-to of water sources for the three study zones. GIS application for this study proved to be an effective approach in irrigation science. Therefore, more spatial plots should be generated to cover major vegetable irrigation regions to inform the decision-making process to guide policies.

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