# Using GIS for Village Level Planning for Agricultural Productivity through Water Harvesting in Semi- Arid Areas of Kitui District

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**KEYWORDS:**
GIS, Sand dams, Agricultural productivity, mapping, Spatial analysis and Expert Approach

**ABSTRACT**

*A study was carried out to investigate the use of Geographic Information Systems in village Level planning in order to improve agricultural productivity through water harvesting in the semi-arid areas of Kitui district. The study considered sub-location, the lowest administrative boundary in Kenya and selected Mbusyani sub-location that has sand dams in comparison to other villages with no water structures constructed. The key factors affecting agricultural productivity were put into consideration in developing maps using the expert approach to analyze them. These key factors are namely location of rivers with existing water harvesting structures, agro-diversity, village population, soil suitability and land resource for irrigation. The analysis involved identifying areas where water harvesting structures would fit best in terms of availing water for irrigation in order to improve agricultural productivity. The population density is being served by the water source in relation to water for irrigation. To finally check the soil suitability for agricultural production and how close it is to the water source. The water harvesting structure used in the study is a sand dam since it is located on the river bed. Maps for the various factors were developed and spatial analysis carried out to identify and develop spatial relationships through overlays and combinations. Finally a suitability village level map built for improved agricultural productivity through water harvesting developed for use in planning.*

## 1 Background

Agriculture is a key sector for people resident in the rural areas of Kenya. Water plays a fundamental role in agriculture: it is essential for livestock and it forms a large part of all plant tissues. For successful agricultural activity there has to be adequate water available on a timely basis and in reliable amounts as well as good soil that can support the growth of these crops. For farming systems in semi-arid areas erratic rainfall causes seasonal dry spells and periodic droughts. For these farming systems increased water infiltration in good soils can improve yields, reduce risk of yield losses as well as increase the recharge of ground water.

Farming under erratic rainfall conditions is pervasive in Kenya: 82 per cent of the land area is designated as semi-arid, holding in excess of one-third of the population [12]. Shortage of water resources and poor soils possess a threat to the economic potential of such areas especially as pertain crop production. The possibility to further agricultural development with such constraints is a key challenge for viable dry land farming. There is a need for a comprehensive, integrated approach to unlock the full potential of sustainable irrigated agriculture for poverty reduction and economic growth in the semi-arid areas. Sand dams shall be used as water harvesting structures in this research. Sand dams are impermeable structures constructed across ephemeral rivers. Their construction substitute for the natural subsurface aquifers that have in antiquity enabled the storage of water in some parts of the river channels.

Expert approach was applied in mapping the potential area where irrigation agriculture can be practiced by coming up with the proper characteristics for sustainable crop production under irrigation. These areas were mapped using GIS enabling identification of areas where water resources can be constructed for full potential agricultural production through irrigation. Suitability maps were generated for irrigation agriculture.

Crops success depends on many things including abiotic, biotic and economic conditions. Suitability is a relative measure of all locations to meet crops abiotic environmental requirements [1]. Considering crops suitability to basic climate and soil traits is an important initial step in identifying potential new crops. Potential irrigated crops that can be of economic value would include vegetables such as tomatoes, kales, cabbages, carrots, capsicum and onions. Irrigated crop performance = abiotic factors + biotic factors+ economic factors. These factors can be summarized by looking at soil suitability, water availability and land availability/ degraded land, [7].

## 2 Study area

The study area was 20 sub-locations in central division of Kitui District, figure 1.0. The District is in the Eastern Province of Kenya is a semi-arid region under agro-ecological zone iv and v situated 150 km East of Nairobi. The total land area is approximately 20,402km$^2$ and is characterized by hilly ridges, separated by low lying areas between 600 and 900 metres above sea level, about 1$^o$ 22' south and 38$^o$1'East. The rainfall amount is (450-900) mm on average. Soils in these areas are sandy, dry and therefore prone to soil erosion by wind and sporadic torrential rains.


Figure 10: Sub-locations in Kitui Central

Farming in Kitui is majorly rainfed with crops such as green grams, cowpeas, pigeon pea, millet, common bean and sorghum grown. There is also agro-pastoral where crops together with animals such as small herds of cows (Boran cattle) and goats are kept. An indicator of the nature (type) and intensity of agricultural activities is the agricultural possessions in the various households. Irrigation of vegetable is carried out along large streams that take a longer period to dry. These vegetables include onions, tomatoes and kales. Land availability is characterized by large parcel of land that is usually cultivated during the rain season and yielding below average [12].

## 3 Methodology

### 3.1 Data sources and specification

There are various data sources used in the research, the GPS location of sand dams obtained from the field, digital topographical map of the scale 1:50,000 for Kitui area from the department of Geomatic Engineering at Jomo Kenyatta University of Science and Technology. Finally sub location and soil shape files obtained from the International Livestock Research Institute Website.

## 3.2 Tools used for data capture

The field data was collected from the field by use of a GPS (Global Positioning System). The field data was significant in the identification of sand dams. Other tools involved in data capture were computer software's such as Arc GIS 9.3 and Arc Hydro extension tool for ArcGis. A field survey carried out to establish highly demanded crops that can be irrigated and whose supply was low

## 3.3 Data preparation/geo-referencing

Digital topographical map of the scale 1:50,000 were projected to clarke 1880 UTM zone 37 south and used for digitizing the rivers used for the study. The shape files were also projected to above mentioned projections.

## 3.4 Data processing

Digitization of the field data using Arc GIS 9.3 was done in order to identification of area where sand dams have been constructed. Clipping of sub-locations from the Kenya sub-locations shape file was done to identify area of study. Using the clipped sub-locations, the soil map for the study area was extracted. The soil map generated was used in extracting the soil PH and soil drainage maps. Digitization of rivers from the 1:50,000 scale topo sheets was done to delineate rivers that were within the areas of study. The rivers were used in extracting the water flow accumulation map. Finally a 30m DEM (Digital Elevation Model) was used to extract DEM for the study area. The DEM was used in generating the watershed and flow accumulation map.

## 3.5 Data analysis

The first involved establishing suitable soils for irrigation crops such as vegetables i.e. kales, spinach, tomatoes, cabbages, carrots and capsicum. Soil suitability in this case involved ensuring the correct PH and drainage that would enable the crop grow well. From experts knowledge the PH and drainage requirements of the mentioned crops are known. The soil PH map was overlayed onto the soil drainage map to establish good soil for the irrigated crops. Figure 2.0 and 3.0 are the soil Ph and Soil drainage maps respectively and figure 4.0 the result of the intersection between the two maps done using ArcGIS.

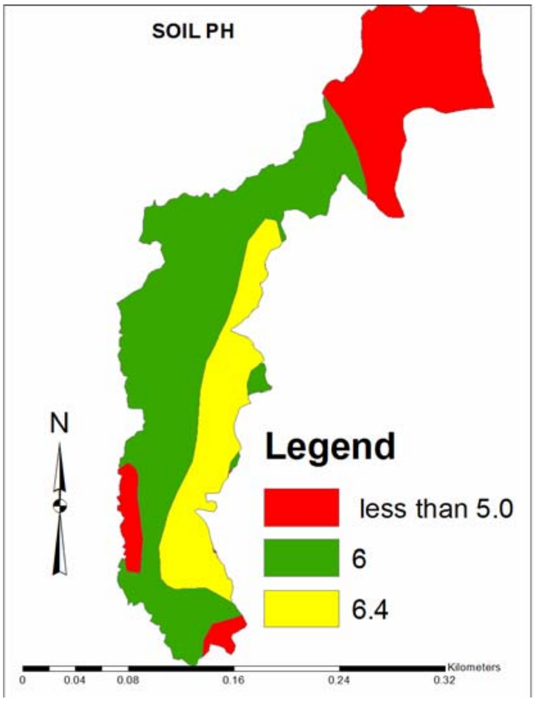



Figure 2.0: Soil PH map

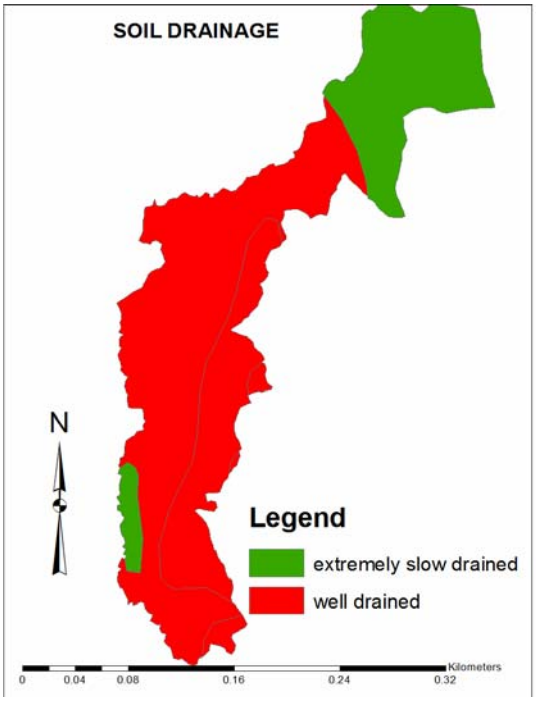



Figure 3.0: Soil drainage map

The results was four classes namely; PH of 6.4/ well drained soils, 6.0 /well drained soils, 0/well drained soils and finally 0/extremely slow draining soils.

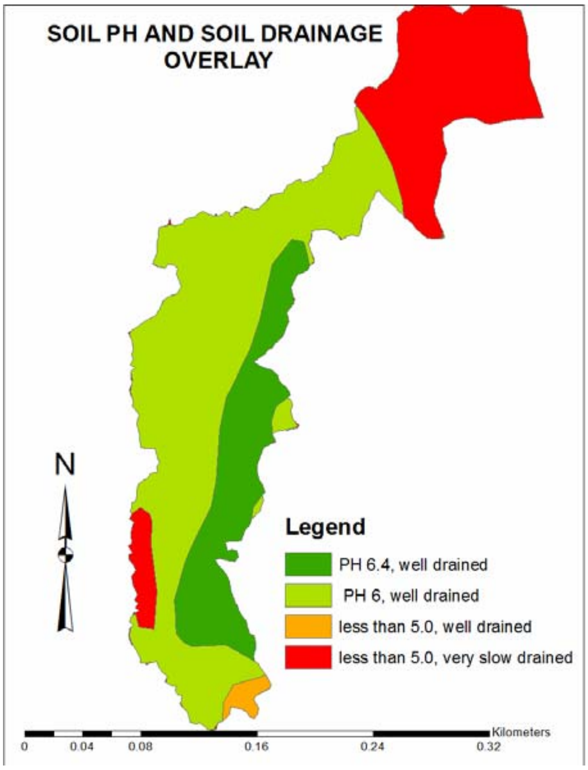



Figure 4.0: Soil PH and Soil drainage overlay

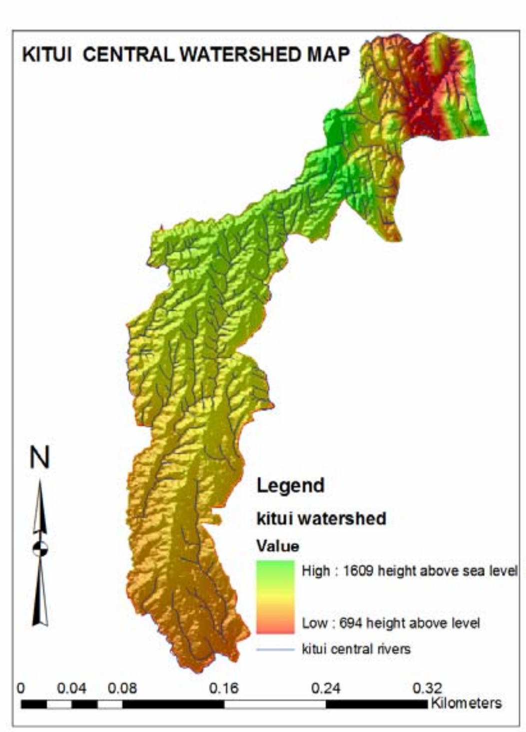



Figure 5.0: Kitui Central

Using the 30m DEM (Digital Elevation Model) map for the study area, a watershed was processed to show the drainage of the study area. Processing of hill shade was also done to enhance visualization of the area. The process for watershed generation involved;

DEM → FLOW DIRECTION → SINK → FILL → DEPRESSIONLESS DEM →

FLOW LENGHT → SNAP POUR → WATERSHED

The result was a watershed map showing the highest to the lowest point of drainage with rivers within the study area also overlayed, figure 5.0 above.

The depressionless DEM was also used in processing the flow accumulation using the Arc hydro tool extension for ArcGIS. The result was water flow accumulation for the study area as shown in figure 6.0. The maps processed i.e. the soil map and the water accumulation maps were compared in order to establish areas where water is available and the soils are also suitable for irrigated crops mentioned previously. The results showed that on areas where the soils were suitable, there were water channels of high water accumulation, figure 6.0.

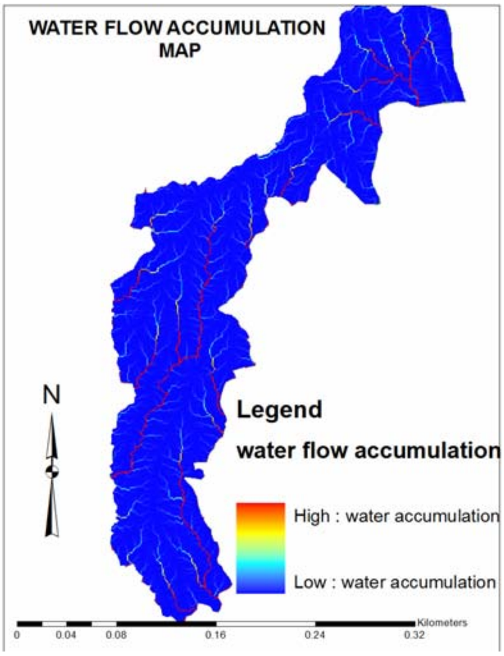
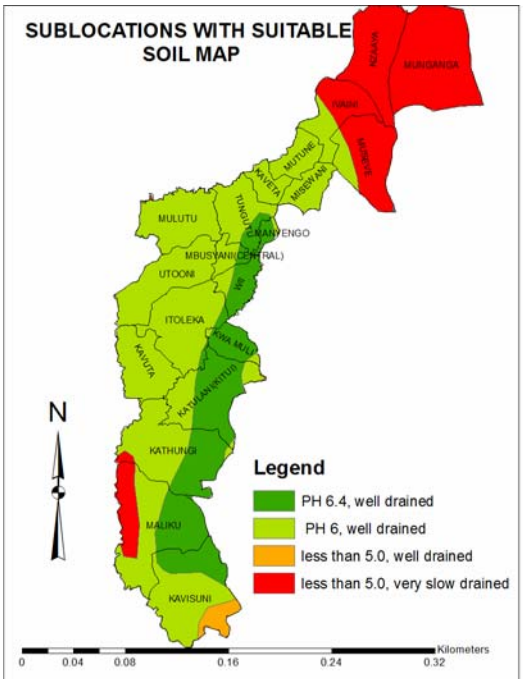



Figure 6.0 Water flow accumulation map

These results were then compared to the sub-location map to establish the number of sub-locations where crop irrigation was possible. 16 sub-locations out of the 20 had suitable soils for irrigation see figure 7.0 below. Out of the 16 sub-location, 13 had high water flow accumulation and hence suitable for crop irrigation for the mentioned crops due to the good soils and water a due to the good soils and water availability see figure 8.0 below.



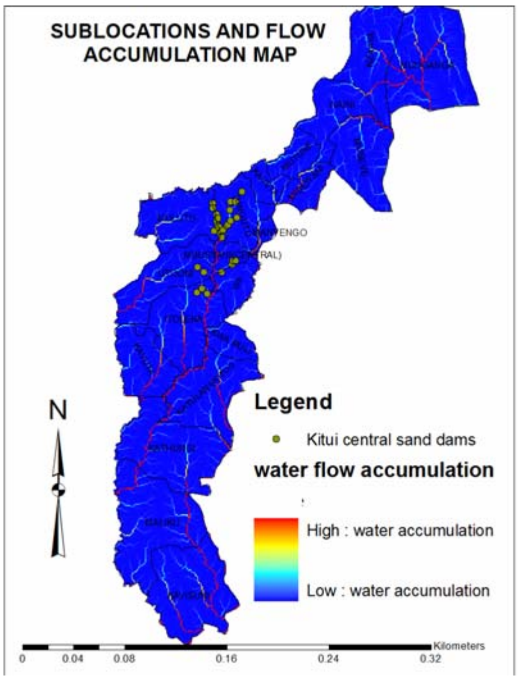




Figure 7.0: Water flow accumulation map

Figure 8.0: Water flow accumulation map

Finally established water structures such as sand dams were overlayed to confirm whether some of them could be utilized for crop irrigation, (figure 8.0). Out the 13 sub-location that were suitable for crop irrigation, 6 had sand dam constructed along the streams. 28 sand dams were considered in the study and 6 were lying in streams of high water accumulation. These 6 sand dams are more likely to sustain multiple uses i.e. irrigation alongside other uses such as livestock watering and domestic use compared to the other dams.

# 4 Discussion

The data analysis was able to identify the sub-locations that have good soils for the irrigation crops mentioned earlier in terms of soil pH and soil drainage. Soil forms the most important non-renewable natural resource determining the success of agriculture in any tract. It was, therefore, essential to make a scientific appraisal of soil resources, especially for their potential and constraints, so that sustainable production is planned. 16 of the sub-location out of 20 were found with good soils for irrigation. The soil PH and drainage for the irrigable crops mentioned earlier are in table 1.0 below;

Table 1.0: crops soil PH and drainage characteristics

| Crop | Soil PH | Soil drainage |
|---|---|---|
| Kales | 6 to 7.0 | Well drained soil |
| Cabbage | 6 to 7.0 | Well drained soil |
| Onions | 5.8 to 7.0 | Well drained soil |
| Carrots | 5.5 to 6.0 | Well drained soil |
| Capsicums | 5.5 to 7.5 | Well drained soil |
| Tomatoes | 6.0 to 6.8 | Well drained soil |

[14], specifies the importance of proper soil PH and soil drainage in dry land farming. Sustainable crop production is possible where suitable soils for the various crops are understood and identified before production can commence. The table above confirms the 16 sub- locations were suitable for crop production. Soil drainage addressed also the ability of the land to become irrigable. 13 of the 16 sub-location had area of high water accumulation and hence availability of water for irrigation. These are streams that can be exploited for irrigation of the crops mentioned above alongside other uses such as domestic use and livestock watering. Construction of water structures such as sand dams that improve ground water recharge would improve on the use of these streams for irrigation [2], discusses on the ability of a sand dam to improve water recharge along streams.

The population of the sub-locations in the study were evaluated and found to fall within the same range and the population density (2009 census) not high enough to put a constrain on water use and land available for cultivation. 6 out of the 28 sand dams were found to be on streams of high water accumulation ad hence likely to function better in terms of ground water recharge compared to the other dams. [8], in the principles of storage dams indicate the importance of the location of the dam especially the ability of that water structure to provide water.

# 5 Conclusion

Proper planning and management of the available resources is key towards addressing food security in the semi-arid areas [4]. The use of geographically referenced data and analysis of factors affecting agricultural productivity is key towards solving agricultural challenges in the semi-arid areas. The results from this research show that the creation simulation planning maps at small scale village level for use in addressing agricultural challenges in the semi arid areas is possible. This information can be integrated into a database that can be retrieved when development issues of the area are being discussed. Farmers and land resource professionals can assess the options that optimize the productivity and sustainable land use.

# 6 Recommendation

A land cover analysis of the study area would have been able to confirm in ha the land available that can be used for irrigation. A developed database of such analysis would be useful for future reference.

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