

**SUITABILITY ANALYSIS FOR LOCATION OF POTATO SUPPLY CHAIN ENTITIES USING GIS AND REMOTE SENSIG IN NYANDARUA CUNTY**

**MUIRURI SAMUEL NJUGUNA**

**PA/00066/015**

**A Research Paper submitted to the School of Economics in partial fulfillment for the requirements of the award of Bachelor of Science (BSc) Degree in Geospatial Information Science with Information Technology**

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## Declaration

This research paper is my original work and has not been presented for a degree in any other university.

REG. NO. PA/00066/015

Sign: ………………………………… Date: ………………………………..

This research paper has been submitted for examination with my approval as University Supervisor.

SUPERVISOR:

Sign: …………………………………….. Date: …………………………………………..

## ACKNOWLEDGEMENT

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## Abstract

Post-harvest loss is a major contributor as to why food products remain expensive while farmers continue to complain about the poor prices. The major cause for his imbalance is the state the supply chain entities being incapacitated to serve the production efficiently. These entities include roads, storage warehouses, and processing industries.

To improve on the speed of delivery to the market, improve value addition on the products and increase returns for the farmers, these value chain entities need to be improved.

The study aims at performing a suitability analysis on areas that require high intervention regarding upgrading the road network, must ideal locations to establish processing industries in order to maximize coverage and most suitable locations to build storage warehouses in order to reach maximum farmers while reducing the travel distance by farmers as well as the traders.

By calculating the median center of each sub-county, the most optimum location to establish a processing industry is determined such that the distance from all sides of the sub county is minimized. It is also located in a way that it remains highly accessible through the major roads.

## Chapter 1: Introduction

## 1.1 Background Information

Potato (commonly known as Irish potato) is the second major source of income and revenue after dairy production in Nyandarua County. Potatoes are fast growing and take much shorter period (75 days) to mature compared to other food crops such as maize and wheat which take up to six months or even one year. This makes it more adaptive to the fluctuating climatic conditions of Nyandarua County that are usually cold and unfavorable for most food crops like maize and beans. Its production in Kenya has been constantly increasing following the call to farmers from the government to diversify their production.

The population of the County as at the last population census of 2009 was 596,268 persons, comprising of 292,155 (49%) males and 304,113 females (51%) (Kenya National Population and Housing Census, 2009). The projected population in 2018 was 712,596 persons; comprising of 349,152 males and 363,443 females (CIDP2, 2017).

In Kenya, potato is the second most important food crop after maize. Its ability to grow in the high-altitude areas where maize does not do well, and its high nutritive value, make it an important food and cash crop for people living in these areas (FAO, 2008). In Nyandarua County, it is the leading cash and food crop.

Despite the fact that there are other counties such as Nakuru, Bomet, Meru and Narok that grow potatoes, Nyandarua County produces about 33% of the total potato production in Kenya (Waithaka M. 2017). This is due to its cool and wet climate with well distributed rainfall all year round and potato varieties that mature fast thus enabling farmers to plant and make a harvest up to three times in one year.

However, the residents face a challenge in the marketing of their produces because of the poor value chain entity facilities and system. The farmers are faced with difficulties in marketing their products due to poor road conditions, lack of specialized storage units, limited processing firms with limited capacity and highly inaccessible marketplaces especially in rainy season. This most of the time leads to exploitation and poor prices given the high perishability nature of the unprocessed potatoes, resulting to great physical and financial loss. The prices also escalate during the recess period, which is usually after prolonged dry period of January which is accompanied by frost that destroys crops in the field, leaving farmers without a harvest and without seed. This situation creates shortages in supply thus making the potatoes too expensive for traders and consumers. There is therefore a need for development of **value addition industries, storage facilities, modern market outlets, and good feeder roads** near the farmers which will ensure controlled and consistent supply that will create some balance and stability in the market price which in turn will ensure that farmers get good returns and traders get reasonable return for their investment and in turn generate more revenue for the county. This should be done because “these facilities are mostly concentrated in and around the consumer markets which provide very little services to the marginal farmers during harvesting” (Kanali C. 2017).

Despite the high potential to contribute in improving welfare of many farmers, potato industry has faced a number of challenges ranging from production, processing, trading and wholesaling and marketing. Potato marketing in particular is poorly structured and farmers generally get very low marketing margin compared to other actors in the value chains. The industrial processing of potatoes is limited to the production of snack type foods such as crisps and other types of snacks specifically for Asian consumers (Kanali C. 2017). The available crisps enterprises are located in Nairobi, over 87km from the County.

The industries will also increase the varieties of products obtained from the potatoes, both the food and non-food products.

This study aims at performing suitability analysis of site allocation on where the different supply chain entities can be established in an effort to reduce the post-harvest loss. The industrial allocation factors will be put into consideration so that the selected locations will have the highest economic value and rate of return.

## 1.2 Problem Statement

Post-harvest loss of potatoes occurs greatly as a result of poorly structured infrastructure that makes up the supply chain entities. That is, road networks, storage units and processing industries.

The road network connecting the farmers to the market are poorly serviced and some are totally impassable during rainy season. Others are too narrow to even accommodate a single vehicle.

Potatoes are highly perishable goods and when stored in unfavorable conditions, they either rot or lose water and sprout leading to loss in taste. Nyandarua County lacks storage facilities that are equipped to provide ambient conditions that can allow storage of up to eight months.

Nyandarua County also lacks capacitated processing industries to add value to potato products. Thus, 90% of the products are sold directly to consumers unprocessed. This shortens the shelf life and increases loss. The by-products that could be processes further to produce other items such as the peelings are considered as waste reducing the overall value the supply chain is supposed to generate.

The need for the supply entities has always been an agenda in the county but precise location where they should be enacted remains a dilemma. The fact that majority of people are not equipped with the knowledge of suitability analysis and location allocation elevates the problem of decision making.

## 1.3 Research Questions

This study will be trying to answer the following questions.

1. What is the state of the current distribution of the supply chain entities in the county?
2. What is the effectiveness of the available supply chain entities on post-harvest loss?
3. How can suitability analysis be used to locate new supply chain entities in order to reduce postharvest loss?

## 1.4 Objectives

The main objective of this study is to perform a suitability analysis for the allocation of additional post-harvest supply chain entities in Nyandarua County in an effort to reduce potato post-harvest loss. The specific objectives will be:

1. To analyze the spatial distribution of the available supply chain entities in county.
2. To determine the relationship between the available supply chain entities and post-harvest loss.
3. To identify suitable locations for additional supply chain entities.

## 1.5 Justification of the study

For every economy to thrive well, good planning has to be undertaken in order to ensure that establishment of industries does not conflict with consistent food production or create ecological imbalance. Sarah (2018) states that the establishment of industries is in the very interest of the societal development but not for individual or political gain.

The population is consistently increasing while the arable land is continually reducing as an effect of desertification, urbanization and demand for more housing even in rural areas. This increased demand for food while the productive land is reducing escalates the risk of a country sustaining itself, to an extent where they have to import food products to satisfy surplus demand, thus creating a need for food security measures.

In its nature, land has vast dynamics that render its utilization uneven. Some areas are more suitable for one type of land use while others are suitable for another and some areas are not suitable at all.

It is in this essence that there is a need to conduct site suitability analysis in Nyandarua County for the possible areas that can be used to serve the different supply chain entities.

This project will be in a position to provide an applicable network analysis that can provide an optimized service area with capabilities to significantly reduce overall production cost while greatly improving quality and availability of potato products.

## 1.5 Scope

In a geographical scope, this study will cover the confines of Nyandarua County. It will target both the small-scale farmers and large-scale farmers in the five constituencies that make up the county.

The research will study how limitation in efficient supply chain entities increase the loss incurred in potato marketing.

The scope that will be studied will involve developing an AHP model which will lay down the factors that influence the location of an industry.

## Chapter 2: Literature Review

## 2.1 General review

Potato industry faces challenges from production processing, marketing, and wholesaling. The poorly structured potato marketing makes the farmer to be the one earning the least among all the actors in the value chain. This leads to the loss of up to a third of the total harvest in terms of physical and financial loss (Kanali C., 2017). This loss is aggravated by the poorly structured supply chain entities such as the cold storage rooms, processing firms and market outlets that are not within the farmers’ reach. The available processors are only located in Nairobi and they only produce crisps thus the amount of potatoes they use for their daily production is way much lower than the amount harvested. Their facilities are also located far from the marginal farmer and he cannot benefit from their storage facilities so he ends up selling his products at a low price so that they don’t spoil in his hands.

One of the big four agendas is food security, potato has a high possibility in aiding the fight against food insecurity because it gives higher yields. However, according to GIZ (2014), per season, 19% of the produce is damaged. The damage occurs from the harvesting to packaging, storage and processing. This is facilitated by the lack of knowledge on the best practices during harvesting, packaging, transportation, storage and processing (Kanali C. 2017).

The supply chain entities that need to be improved are:

1. Establishment of specialized cold storage units- the potatoes are a vulnerable product, when exposed to heat and light, they lose a lot of water and lose the taste. Also, when stored in a dump location, they rot and tones of potatoes are lost.
2. Market Outlets- there is a need to create market outlets that are specialized to handle the potatoes. These platforms will create outlets for local and international trade of potatoes that are fresh and of high quality.
3. Processing units- The county needs processing units. This will increase the market base for potatoes needed for processing. This in turn will diversify the potato products in the market and increase the shelf life

Due to this fact, there is a need to perform land suitability analysis in order to determine the most suitable locations to set up these facilities.

Establishing food manufacturing industries should be treated as a rural development strategy because the value-added activity can increase farm incomes through backward linkages to agricultural production with increased commodity demand, in addition to employment opportunities they provide (Capps, Fuller, and Nichols; Kane and McNamara). Locating the potato processing industries in the rural areas will reduce the bulkiness of the commodity and thus cut on the cost of transportation.

Locations are chosen to gain access to labor, capital, business services, transportation, and technology while meeting procurement/distribution requirements of the firm (Henderson J. R., 2000).

Land suitability analysis is the process to determine whether the land resource is appropriate for some specific uses and to determine the suitability level by considering different factors such as land use and land cover type, landscape, and road infrastructure (Manlun 2003). Land suitability analysis is important in determining land resource for specific function in a given area. Locational analysis encompasses any spatial analysis of the area like proximity to the different services. Physiographic feature describes features and attributes of the land surface (Mathias Tesfaye Abebe 2017).

Industrial location is an important factor at local, regional, national or even national level. It is influenced by a number of factors such as “transportation, labor, raw materials, markets, industrial sites, utilities, government attitude, tax structure, climate, and community.” (Badri M. A., 2007). Some other factors such as environmental impact of the industry, the supply of both agricultural and non-agricultural raw materials and availability of land and infrastructure (Sule Turhan, Basak Canan Ozbag and Bahattin Cetin, 2007).

## 2.2 Digital Elevation Model (DEM)

Digital Elevation Models (DEM) is a GIS raster data type that represents earth’s surface as a regular arrangement of locations where each cell stores a value corresponding to its elevation. This allows for systematic analysis of the relationships among places and their characteristics. Technological advancement of sensor and satellite imaging has contributed greatly to the generation of DEM from Remotely sensed data. The Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) is a sensor used to record spatial data that is used to generate DEM.

To enhance and extract the exact DEM, topographical attributes play an important role. These attributes are:

1. Primary

These are the attributes that are delivered directly from DEM.

They include:

1. **Surface derivatives**

This measures the rate at which elevation changes as per the location of elevation.

1. **Slope**

This measures the rate of change of elevation in the direction of the steepest descent.

1. **Aspect and Primary flow direction**

Aspect is the orientation of the line of steepest descent. It helps in visualizing landscapes.

In this report am going to used Hill shade and Triangulated Irregular Network to represent the terrain of Nyandarua County in order to visualize the general topography of the area.

## 2.3 Physiology of Nyandarua County

Depending on the predominant volcanic rock type, the southern area can be divided into three distinct units: Kinangop plain, Niadarawa and Elephant mountains of Aberdare Ranges.

The northern area is in the Ol borosat plain, consisting of Ol Kalou, Ol Joro Orok, and Ndaragwa.

Kinangop area is at an elevation of about 8800 feet near Kijabe and gently sloping towards the Northern side with an elevation of about 8200 feet at the northern side.

The area has a number of tributaries that dissect it. Mkungi, Turasha, Kitiri among others are tributaries of Malewa River which drain into L. Naivasha. Others such as Chania, Sasumua, and Kimakia are tributaries of rivers Athi and Tana which discharge into Indian Ocean.

This is the area that is comprised of Niadarawa (12,816 feet) and Elephant (11,900 feet). The mountains have a radial drainage. They are covered by a forest with the vegetation rising to a height of about 10000 feet. The area consists of basaltic agglomerates.

Ol kalou is at an altitude of 7890 feet. It consists of many building rocks.

Ndaragwa is in the farthest Northern side towards the end of Aberdare Ranges. It is at an altitude of 7660. The predominant rock type in this area is Laikipian Basalt.

**Rock Types**

The common rocks observed in the area are basalts, basaltic agglomerates, trachytes, and phonolites, pyroclastic and lacustrine deposits.

The oldest rocks in the area are the Simbara Series, which are believed to be of Miocene age. They are overlain by basaltic agglomerates and autobreccias. These can be observed as outcrops on Niadarawa and the Elephant.

The other type observed in the southern region is the Sattima Series which compose of phonolites and trachytes of age between Kamasian and Pliocene. These have been observed over an extensive area ranging from the Kikuyu special area in Kiambu, through Laikipia and even up to Nyeri in Othaya. They are therefore the major rock type covering the study area.

The younger rocks in the area are the Pleistine Volcanic and Holocene Sediments. These are observed on aberdare vents and around Kijabe Hill. They are believed to be eruptions of Longonot that reached south western part of the area.

**Conceptual Framework**

Data Collection

Research Design

Standardizing the Data

Create a GIS Database

Multi-Criteria Analysis

Perform GIS Analysis

Land Suitability Map

## Chapter 3 Research Methodology

This topic will cover details on the research design that was used for this study, the study area where the research was carried out, methods and tools that were used in the data collection and the sampling techniques used during the study.

## 3.1 Research Design

According to Selltiz C. as cited by Kothari C. R. in *research Methodology*, “research design is the arrangement of conditions for collection and arrangement of data in a manner that aims to combine relevance to the research with economy in procedure.”

This study is used **diagnostic design** for it was performing the suitability analysis of supply chain entities and diagnosing their effectiveness in reducing post-harvest loss in potato production. The weighting models of the multi-criteria evaluation were used in order to test and diagnose the suitability of selected areas for development.

## 3.2 Study Area

Nyandarua county lies in the central part of Kenya between latitude 0°8’ North and 0°50’ South and between Longitude 35° 13’ East and 36°42’ West. Nyandarua borders Nyeri to the East, Laikipia to the North, Nakuru to the West, Murang’a to the South East and Kiambu to the South. The County is mainly linked to the major town centers in the region (Nakuru, Nyeri and Nyahururu) by road, the dominant mode of transport.

Nyandarua County covers an area of 3,245.2 Square Km lying between latitude 0°8’to the North and 0°50’to south and between 35° 13’East and 36°42’ west. Nyandarua County is divided into five Sub-Counties namely: Ol kalou, Kinangop, Kipipiri, Ndaragwa and OljoroOrok and further into twenty-five wards. It had a population of 596,268 people, according to the 2009 National Census.

Nyandarua is one of the Kenyan Highlands. The topography of Nyandarua County constitutes of a mixture of plateaus and hilly areas. The County’s physiography was as a result of volcanism and faulting that created the major land. The highest point

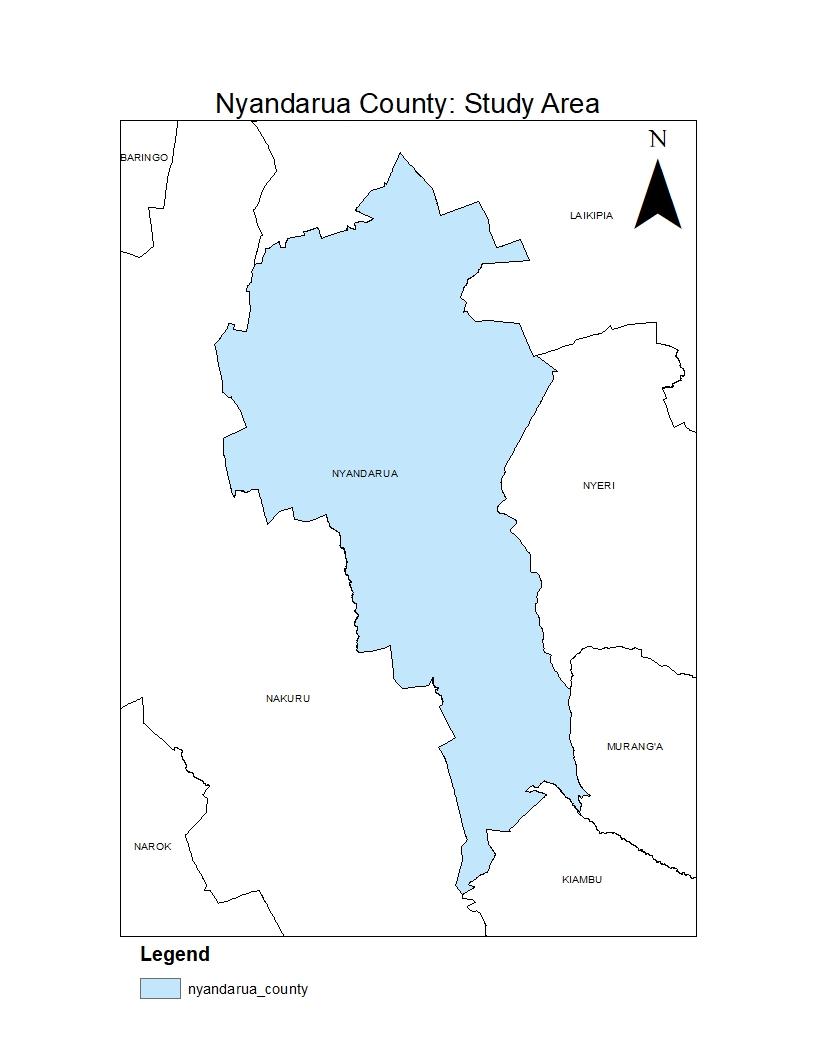
****of the Aberdare Ranges is about 3,999 meters above sea level. The lowest parts include Lake Ol’Bolossat, Leshau and the northern part of Central Ward, lower Kaimbaga and the western parts of Kipipiri, Githioro and Murungaru Wards. The flat areas include Kinangop and Ol kalou/OljoroOrok plateaus. The county has eight permanent rivers namely; Malewa, Ewaso Narok, Pesi, Turasha, Chania, Kiburu, Mkungi and Kitiri. Lake Olbolossat which is the largest water mass in the county is fed by streams and underground water seepage from the Aberdare and Dundori hills.

Figure 1: study Area

Nyandarua County has a cool and wet climate with reliable well distributed rainfall. In a typical year, the county experiences two rainy seasons: long rains from March to May with a maximum rainfall of 1,600 mm and short rains from September to December with a maximum rainfall of 700 mm. The average annual rainfall of the county is 1,500 mm (CIDP2, 2017).

## 3.3 Data Collection Methods used

The data collected for this study was from both from primary and secondary sources. The primary data source were observation, interviewing, questionnaire administration and GPS coordinates recording.

The secondary data source use was obtained from the publications from other studies, Google Earth images, and remote sensing images from the internet.

## 3.3.1 Observation

Though observation is not a scientific tool, when it serves a formulated research purpose and systematically and recorded and subjected to checks and controls on validity and reliability, then it becomes a scientific method (Kothari C. R., 2004).

The observation method is used to collect data without getting it from any respondent. The researcher gathers the information by looking for themselves.

Due to the subjective nature of this method, this study will utilize the *structured observation*. This is because the structured observation provides guidelines on the selection of the data to be observed, units to be observed and the style of recording the observed data. The tools that were used for this method are:

1. Camera- I used phone’s camera to take photographs for different potato farms and products
2. Checklists- these were used to countercheck whether all the information that was to be collected has been met.
3. GPS Receiver- this will be used to collect the geographic coordinates of the physical entities that observed on the ground.

## 3.3.2 Interviewing

This is a data collection method that involves the researcher gathers the information from the respondents orally. The interview can be *personal* where the researcher and the respondents meet face-to-face or *telephone interview* where the researcher communicates with the respondent over the telephone.

This study used personal interview where interaction with farmers, traders and authority personnel to obtain the key matters on the state of the supply chain entities under study was done on site face to face. This method helped in obtaining firsthand information on how these different parties handle their products after harvesting and how insufficient supply chain entities contribute to the post-harvest loss.

This method was used to obtain deep insights from farmers and traders regarding the challenges they face in the supply chain entities and to collect suggestions on what can be done to improve the state of the matter.

## 3.3.3 Questionnaire Administration

A questionnaire constitutes of a set of structured questions that are either typed or printed. It is administered to the respondents and they fill in the questions therein thus giving the researcher the information. The questions can be either closed or open ended.

Information from the farmers was collected using structured questionnaires which composed of classified questions tackling different levels of production and handling of potato after harvesting.

## 3.3.4 Secondary Sources

The secondary sources of data that are were used for this study included:

1. Google Earth images

The Google Earth images were used as base maps for the analysis. They were used as a source of data for digitization in order to obtain vector data for the purposes of further analysis. The images were also used to generate elevation data.

1. Survey data

This study used shapefiles from Kenya Data that was used to delimit boundaries of the different sub counties and clip features to the confines of the county. This also provided spot elevation data that was used to develop digital elevation model (DEM).

1. Journals and Publications

These materials will be used to give more information about the topic of the study. They will include the county policies and plans, publications on suitability analysis and on factors that influence industrial location. These assisted in giving a detailed and informed decision why and where to locate the different supply chain entities.

These were obtained from the different county departments as well as from the internet.

## 3.4 Sampling Methods

Sampling is the “selection of some part of an aggregate or totality on the basis of which a judgment or inference about the aggregate or totality is made” (Kothari C. R.).

Sampling enables the researcher to save on time and money. The study does not have to be carried out in the whole population but a section of the population may be used to represent the rest. This helps the researcher to conduct the study faster and with less resources.

In this study, Multi-stage sampling was used. This involved selecting a number of wards from the sub-counties then a number of farmers from each ward. A total of 80 farmers were selected by selecting 8 wards and 10 farmers from each ward.

## 3.4 Data Analysis and presentation Methods

The data obtained from the questionnaires was tabulated in a manner that it could be queried to give summaries of different cases. For this study, SPSS was used as the tools to tabulate and analyze the data.

Pie charts and summary tables were used to present descriptive data. These were used to visualize the percentage count in each category of questions.

Spatial analysis results were presented in form of maps. The spatial analysis carried out included proximity analysis, network analysis and interpolation.

Network analysis was carried out to determine the area that fall within the distance assigned to the criteria. Interpolation was conducted in order to derive the general topology of the area.

For the multi-criteria analysis, the factors considered were:

* Distance to the road. The areas closer to the road were considered as more suitable than the areas further from the road.

## Chapter 4: Analysis and Findings

## 4.1 descriptive statistics from the questionnaire and interview

This section will discuss some of the charts from the respondents, obtained from the questionnaire and interviews, depending on their importance to the scope of this study. A table containing all the respondents can be accessed online via the following link: <https://samizzothegeek.github.io/GIS_Site_Analysis/>

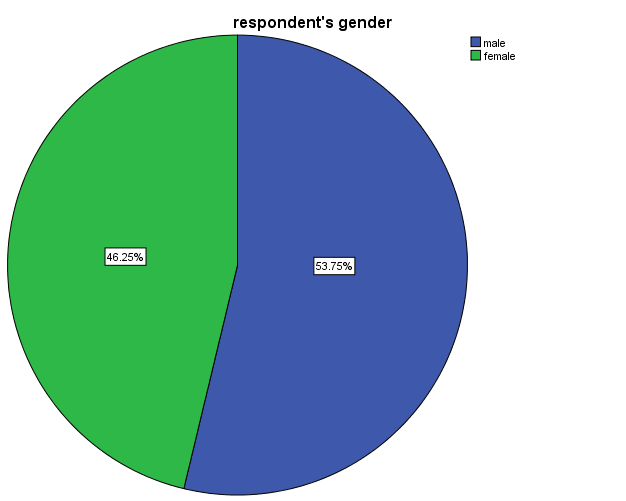


Figure 2: Gender Count

Out of the 80 respondents who responded o questionnaires, 53.75% were male whereas 4625% were female. This is an indicator that most of the land ownership, either by title deed or by leasing is dominated by males.

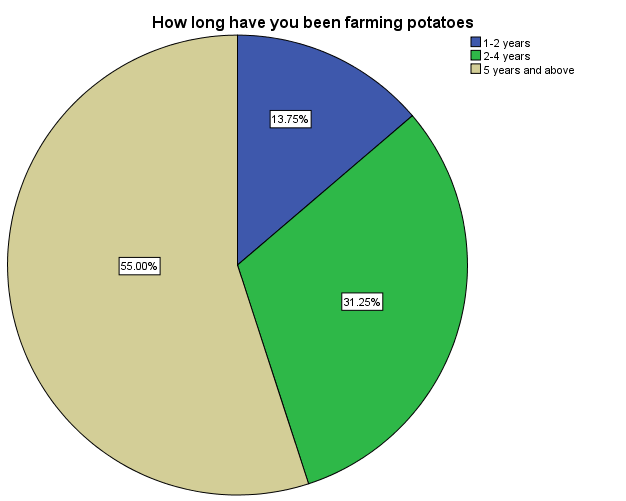
Potato being the major food and cash crop, the majority residents of the residents have been involved in potato farming for as long as they can remember. 55.00 of the respondents said they have been arming potatoes for over five years. Most of the people in this category said farming is their primary source of income and with improved infrastructure, they can be able to increase their return and minimize the losses incurred. 31.25% said they have been farming potatoes for a period between 1 and 2 years. This group comprised mainly of people who have recently moved to the county or have retired from civil servant jobs.

Figure 3: Farming Duration

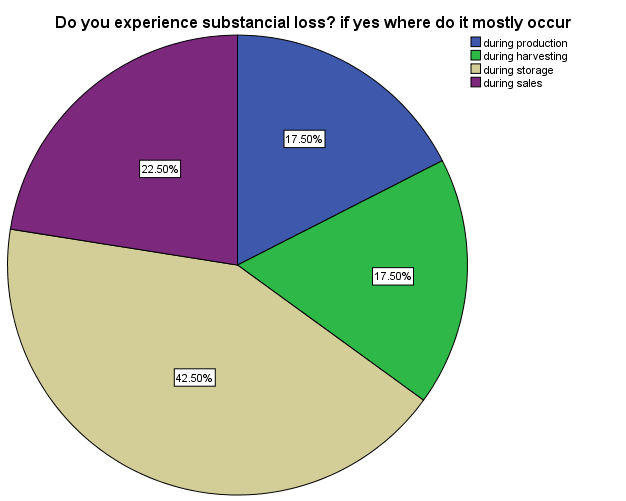
From the study, 42.5% of the respondents said that substantial loss of their products is experienced during storage. They associated their loss with lack of specialized way of storing their products. The major cause of damage is sprouting, rotting, pest and disease, such as millipedes and rats. 17.50% said that they experience much of their loss in harvesting, and production while the rest 22.5% said that they experience loss during sales.

Figure 4: Loss occurrence

25% of the respondents sell to brokers who later sell to the other stakeholders in the supply chain. They associated this to lack of a better way to reach to the market.

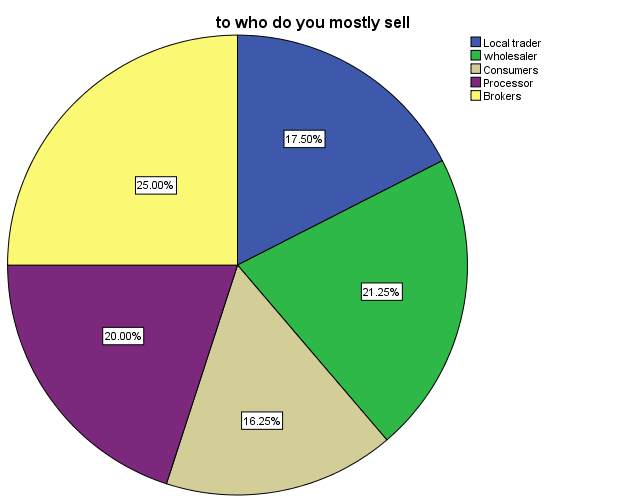
21.25% sell directly to wholesalers, 20% sell to processing firms and businesses, 17.5% sell to local traders who include local resellers and hotels while the remaining 16.25% sell directly to consumers

Figure 5: Buyer

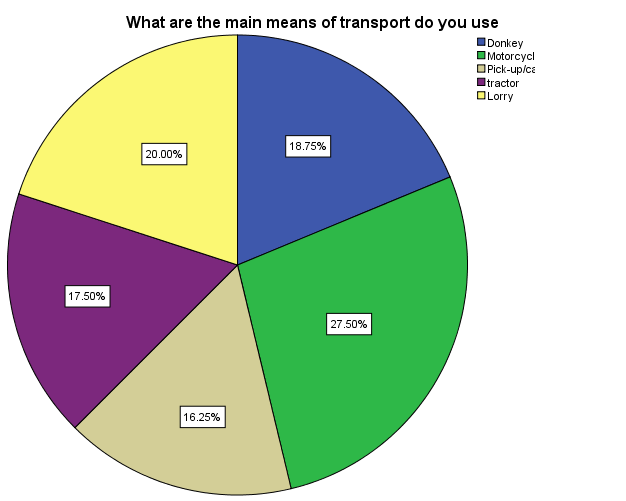
Another important aspect was the means of transport used by the buyers and farmers to get their products from the farms. 27.5% said at one point or another they use motorbikes to get the products from the farms to a point where the customer is or where they can be carried by the lorries to the market. 18.75% and 17.5% said they use donkeys and tractors respectively especially during the rainy season when lorries cannot reach the farms do o inaccessibility of the roads. 20% said they use pick-up trucks and personal cars to get their products to the market or to their homes for storage.

Figure 6: Means of Transport

On the matters concerning protection from the sun, the respondents said that the methods used to protect the potatoes after harvesting included covering with leaves 22.5%, putting then under the trees shade 12.5%, putting thing in bags 20%, moving them o he store immediately 23.8% while 21% said they do not protect their harvest, they either sell immediately or leave them uncovered

Table 1: Protection From Sunlight

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **How do you protect the harvest from direct sunlight** | | | | | |
|  | | Frequency | Percent | Valid Percent | Cumulative Percent |
|  | cover the tubers with leaves | 18 | 22.5 | 22.5 | 22.5 |
| Put them in the Shade | 10 | 12.5 | 12.5 | 35.0 |
| Put them in the bag | 16 | 20.0 | 20.0 | 55.0 |
| move them to store immediately | 19 | 23.8 | 23.8 | 78.8 |
| Do not protect | 17 | 21.3 | 21.3 | 100.0 |
| Total | 80 | 100.0 | 100.0 |  |

From the above analysis, it is evident that the currently available supply chain entities are not enough to serve the entire county and some of the areas are still facing challenges in getting their products to the market. The residents also do not know he best practices of how they can store their products to last longer without going bad.

## 4.2 Spatial Analysis

There is only one potato warehouse and one processing firm in the whole of Nyandarua County; both of which are in South Kinangop, the processing firm in Njabini and the storage warehouse in Murungru. These facilities have limited capacity and do not serve the residents fully. The road network is also poorly maintained. Major roads in Nyandarua are Class C roads which are usually three inches thick and start developing potholes in less than five years. Some of the class C roads are not even tarmacked. The larger part of the county is covered by lower class roads which are under county government and Rural Road Authority. These roads are either graveled or just graded. When it rains, the roads develop furrows so deep that not even a lorry can pass.

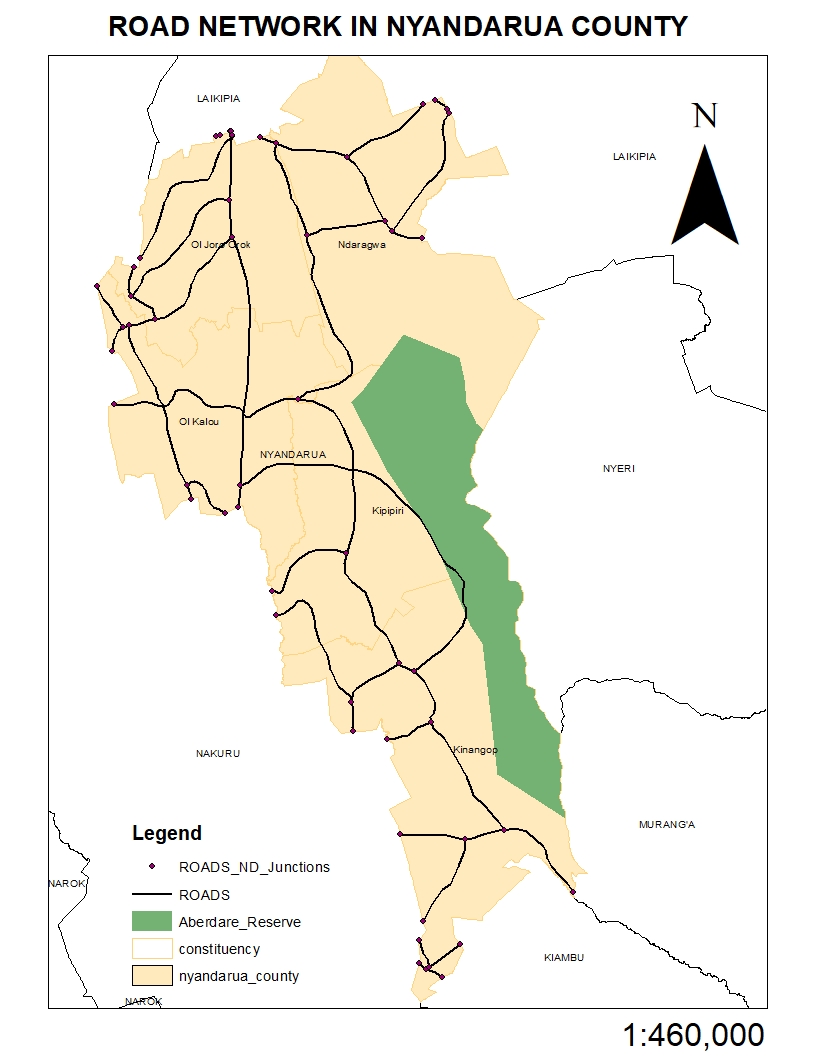


Figure 7: Road Network

The figure above is a road network maps for roads of Classes A to D. But it is evident from the map that most of the areas in Nyandarua are still uncovered despite the fact that they are habited.

## 4.3 Suitability Analysis

The suitability analysis was carried out from the coverage of the current roads of classes C and D. A multiple ring buffer of 2km, 3km and 5 km was conducted to represent area that are highly suitable, suitable and least suitable.

**4.3.1 Accessibility of the area**

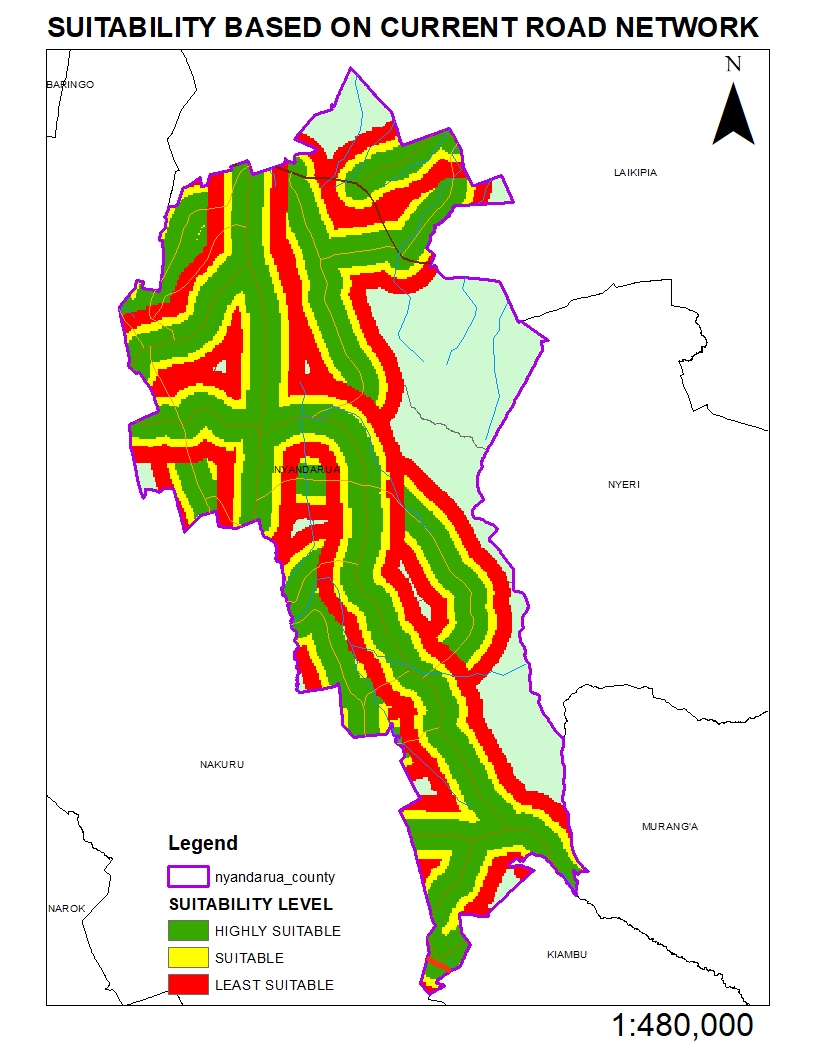
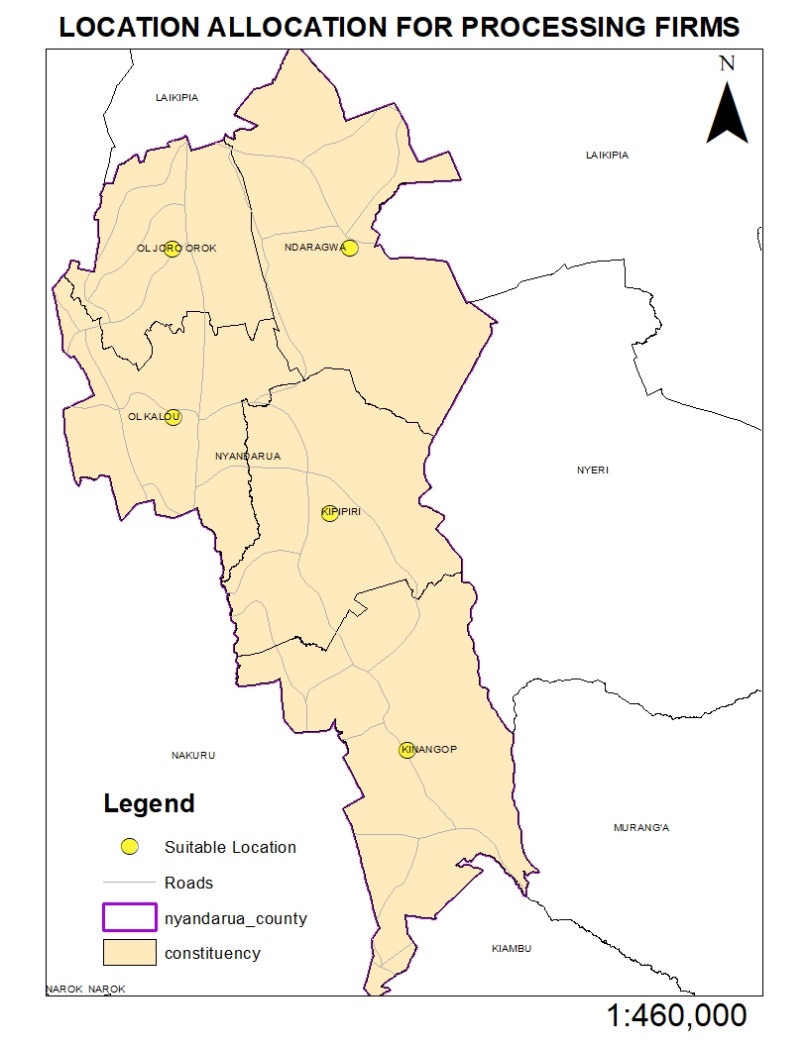


Figure 8: Suitability based on road nework

From the figure above, it can be derived that if the current road network is improved, the entire area will be well serviced and feeder roads, less than 5km will connect farmers to major roads. This will establish efficient connection that will speed up the delivery to the market thus reducing post-harvest losses.

The processing firms and storage facilities located within this buffer zones will be highly suitable or farmers as well as business people.

**4.3.2 Location allocation**

For the processing firm, one firm per sub-county will be ideal to handle the potato products from that sub-county so that the products will be transported from the county while they have undergone value addition. The bulkiness of the end product will also be reduced thus the transport cost will be lower translating to more returns for farmers and traders.

By calculating the median center for each constituency, it was possible to obtain an ideal location that minimizes Euclidean distance from any part of the constituency.

Figure 9: Suitability for Location of Processing Firms

## 4.3.3 Allocating Storage Warehouses

The harvested products require a place where they can remain fresh for a substantial duration before being transported to the market or to the industry for processing. That is why there is need for storage warehouses.

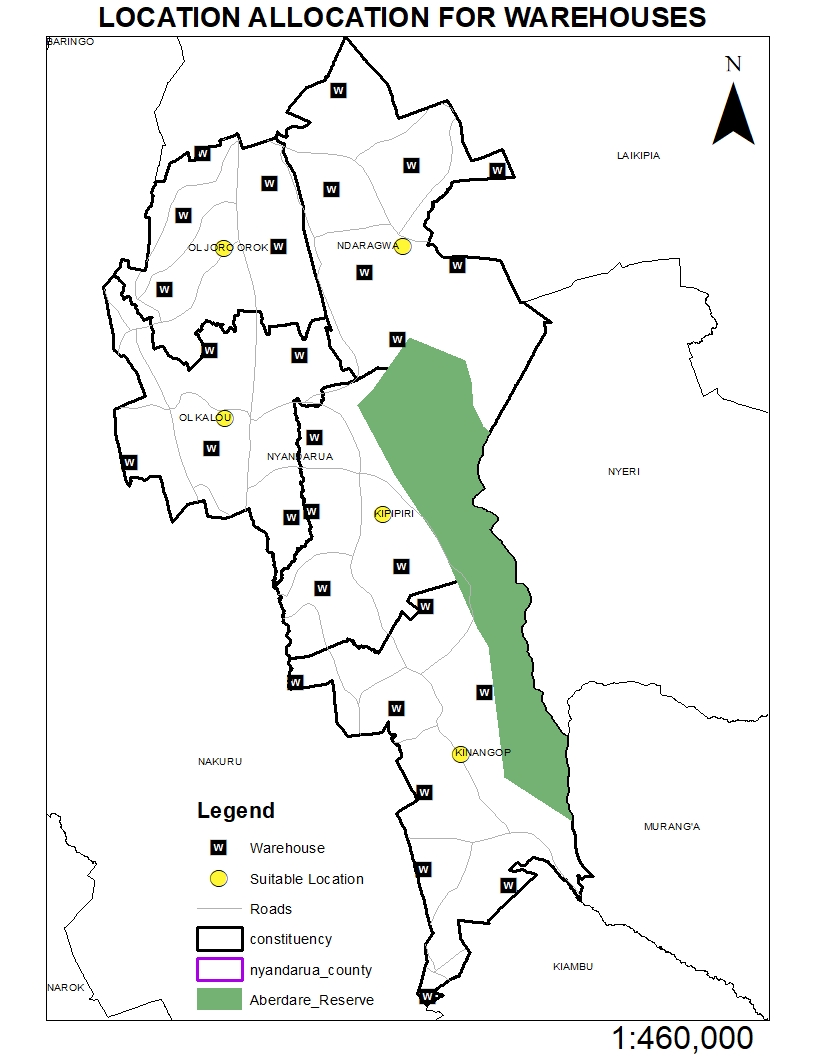
By locating the storage warehouses in the least accessible areas, they will serve as collector points for processing firms and business people. He farmers will no longer be worried about their products going bad due to over storage in wait for better prices or impassability of the roads.

Figure 10: Warehouse Allocation

The warehouses will also be able to create an economic pool large enough to influence upgrading and maintenance of the connecting roads.

## 4.3.4 Suitability Map

By considering all the supply chain entities analyzed, that is, storage facilities, road network and processing industries, the suitability map below was generated. that when implemented, it can significantly reduce post-harvest potato loss and increase returns for farmers and revenue generation for the government.

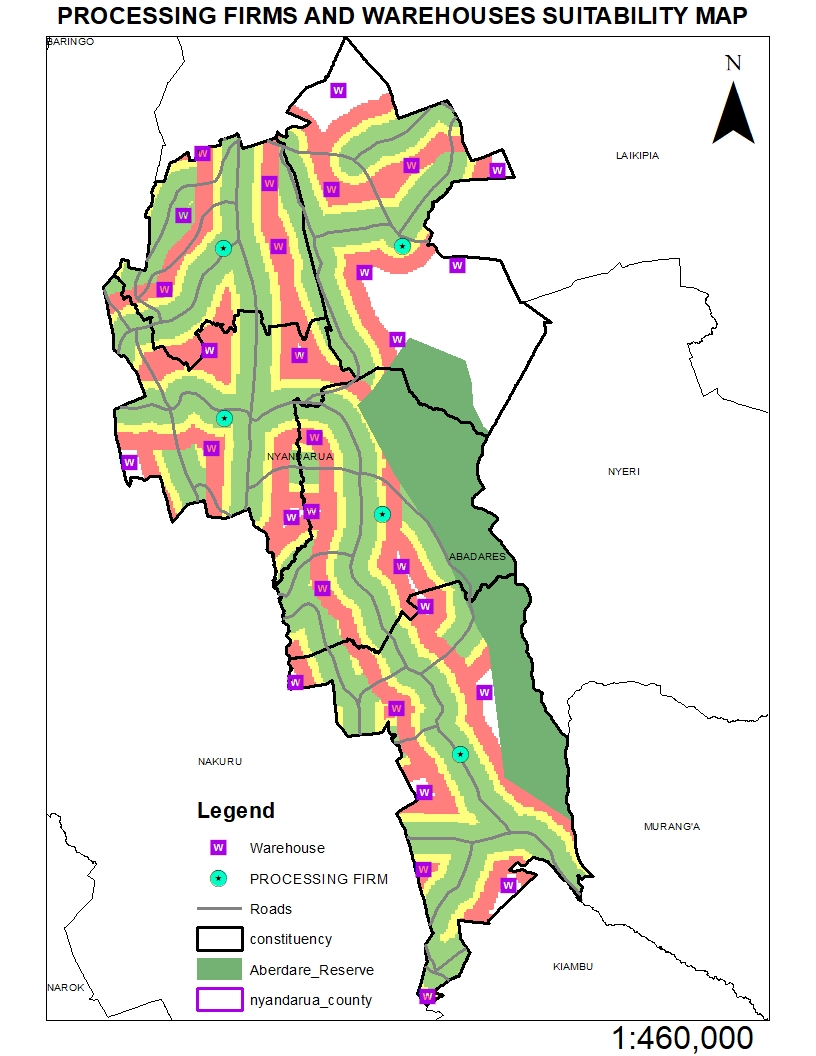
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Figure 11: SUITABILITY MAP

## Chapter 5: Conclusion and Recommendations

## 5.1 Conclusion

The objective of this study was too establish the association of potato supply chain entities with post-harvest loss, and where these facilities can be put up o curb this loss. From the available literature and analyses in the preceding chapters, it can be inferred that there are limited number of supply chain entities. Road network is also not well serviced. This limited infrastructure has proved to directly influence the amount of post-harvest loss along the supply chain.

There is therefore need for upgrading major road and servicing the feeder roads in order to ensure efficient flow of products from the farmers to the market. There is also need to construct potato processing firms which will impact value addition and raise farmers’ revenue by putting into use even the products currently considered as waste such as peelings. The county also requires specialized storage warehouses to hold harvested product in wait to be taken to the processing firms or consumers.

## 5.2 Recommendations

Upgrading of all class C roads to bitumen

Upgrading all he class D roads to all-weather state, by tarmacking them and servicing them regularly.

Servicing all the feeder roads to ensure they are passable all seasons.

Constructing at least one processing firm in each sub-county.

Construct at least four storage facilities in each sub-couty, starting with the least accessible areas.

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Appendices

**Appendix I: Questionnaire-Farmer**

My name is Samuel Njuguna Muiruri, a fourth year student at Maseno University doing GIS with IT. Am doing a study on suitability analysis for potato post-harvest supply chain entities (stores, processing plants and markets) in Nyandarua County as partial fulfillment for the award of my degree. Please help me by answering these questions. The data you fill will be used for academic purpose only and will be treated with utmost confidentiality.

Farmers name (optional):\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. **Respondent’s gender**

* Male
* Female

1. **How long have you been farming potatoes**

* 1-2 years
* 2-4 years
* 5 years and above

1. **What are the main challenges in potato production?**

* Market demand
* Prices
* Extended bags
* Mechanization/machinery in production and harvest
* Diseases
* Inputs (fertilizers, pesticides)
* Certified seed
* Irrigation
* Storage
* Losses
* Others

1. **Do you experience substantial losses in the production, harvesting and sales of your potatoes? If yes, where does this mostly occur?**

 During production

 During harvesting

 During storage

 During sales

 No

1. **What was your total portion of land under potatoes harvested last season?** \_\_\_\_\_\_acres
2. **What was the total quantity harvested from the largest portion of land?**

**Quantity Units in bags**

Total quantity harvested

Potatoes from plot sold

Potatoes from plot stored as seed

1. **How do you protect the harvested potatoes from direct sun**?

 Cover the tubers with leaves

 Put them in the shade

 Put them in the bag

 Move them into the store immediately

 No

**8. Do you harvest potatoes when it is raining?** 0 = No 1 = Yes

a. **If yes,** what is the estimated damage caused by harvesting when it is wet?

\_\_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_\_ kg per ¼ acre

**Unit codes** 1. 17 kg bucket 2. Crate (50 kg) 3.bags (110kg)

**9. How long do you store your harvest?**

 do not store

 1-2 weeks

 2-4 weeks

 over 4 weeks

**10 Why do you store them?**

 1. To wait for better prices

 2. Seed potatoes

 3. Lack of markets

**11. What quantity of harvested potatoes from the portion of land was stored?**

\_\_\_\_\_\_\_\_\_bags

**12. Do you experience any losses/ damages due to storage?** 0 = No 1 = Yes

**13. If yes, what causes the losses/damages?**

 Rotting

 Pests and diseases

 sprouting

**14. What quantity of potatoes are lost/damaged due to storage?**

i.\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ ii. In weight\_\_\_\_\_\_\_\_\_\_\_\_kgs

**Unit codes** 1. 17 kg bucket 2. Crate (50 kg) 3. Other (specify)\_\_\_\_\_\_\_\_\_\_\_

**15. Do you sort and grade your potatoes?** 0 = No 1 = Yes

a. If yes, at what stage do you grade?

 During harvest

 Just before storing

 When selling

 (Other specify)\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**17. What are the main means of transport?**

 Donkey

 Bicycle

 Motorcycle

 Tractor

 Pick-up/car

 Lorry

**18. Who packs the bags for selling?**

 1. Farmer

 2. Brokers

 3. Trader

 4. Employees/workers

**To who do** **you mostly sell?**

 1. Local trader

 2. Wholesaler

 3. Consumer

 4. Processor

 5. Brokers

**19. What are the current, lowest and highest prices of the type of potato bags you have**

**sold in the recent past to local traders?**

Type of bag recently sold Current price (KES)

Lowest price and month Price (KES) Month

Highest price and month Price (KES) Month

**Appendix II: Interview checklist – Processing firm**

My name is Samuel Njuguna Muiruri, a fourth year student at Maseno University doing GIS with IT. I am doing a study on suitability analysis for potato post-harvest supply chain entities (stores, processing plants and markets) in Nyandarua County as partial fulfillment for the award of my degree. Please help me by answering these questions. The data you fill will be used for academic purpose only and will be treated with utmost confidentiality.

1. What potato products do you processor produce?

2. What varieties are suitable for producing each product?

3. What qualities do you look for when choosing the varieties to produce each product?

4. What are the shortcomings in each variety chosen for each product?

5. From where do you get your potatoes?

6. What problems do you have when acquiring the varieties they need?

7. Do you contract farmers? If yes, what are the pros and cons of contract farming?

8. Are there any problems associated with potato bags and the materials used for the supply of potatoes?

9. If yes, describe the potato bags and materials, and the problems associated with each.

10. What is the current buying price for each size of bag bought?

11. Which months of the year have the highest and lowest buying prices and what are those prices?

12. How are potatoes transported from the farm to the processing point?

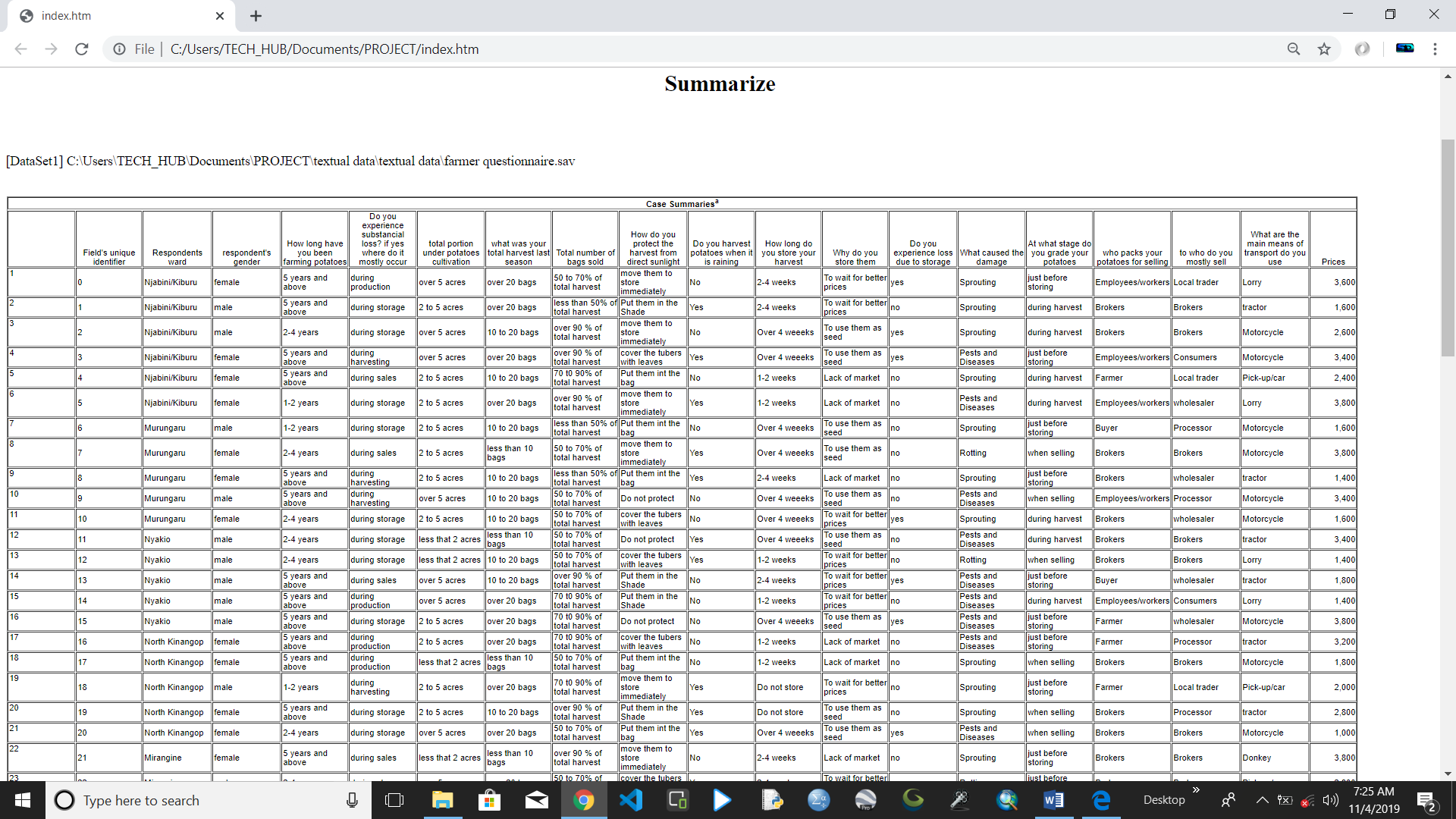
13. How do you load and off load potato bags on to/from the means of transport you use?

14. Do you experience any losses from processing potatoes?

a. If yes, how do the losses occur? How much is lost at each stage of processing?

15. What are the main challenges experienced when dealing with potatoes?

**Appendix III: Summary Questionnaire Response**

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