ONION CULTIVATION SYSTEM AND SPATIAL DISTRIBUTION CENTERS IN TAHOUA REGION/NIGER

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Abass A. Mallam

ONION CULTIVATION SYSTEM AND SPATIAL DISTRIBUTION CENTERS IN TAHOUA REGION/NIGER

Onion farming is the main irrigated crop that contributes to the economy of the Tahoua region, Niger. There are two factors that promote the outstanding potentialities of onion cultivation in Niger: the best productive variety “Violet Galmi”, and it is well adapted to storage. It is produced during both growing seasons which creates a permanent local supply of onions all year. Much of the producing areas are not accessible by road, which inhibits the marketing network. Farmers are in need of an improved transportation system in order to further develop onion production. The Violet of Galmi is grown by all the onion producers of Niger. This onion has a major importance in the socio-economic life of the Nigerien population. The consumers appreciate its cooking qualities and spicy taste. It also has a commercial advantage in the local and the sub-regional markets.

Frederick L. Bein, PhD, Chair

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INTRODUCTION

Agriculture is the major economic activity occupying 90% of the people of Niger. Subsistence farming dominates, while commercial farming is increasing in importance. Because of the irregularity of rainfall, rain-fed crops fail to cover the needs of the population. In addition to this, there is a general shortage of underground water for irrigation as well as a lack of advanced technology for collecting that water. Niger places its effort to reduce human poverty by developing agriculture in the rural sector. One goal of Niger and its Non-Governmental Organization (NGOs) partnerships is to develop groundwater and surface water controls systems (mini-dams, reservoirs and boreholes) to enhance irrigation.

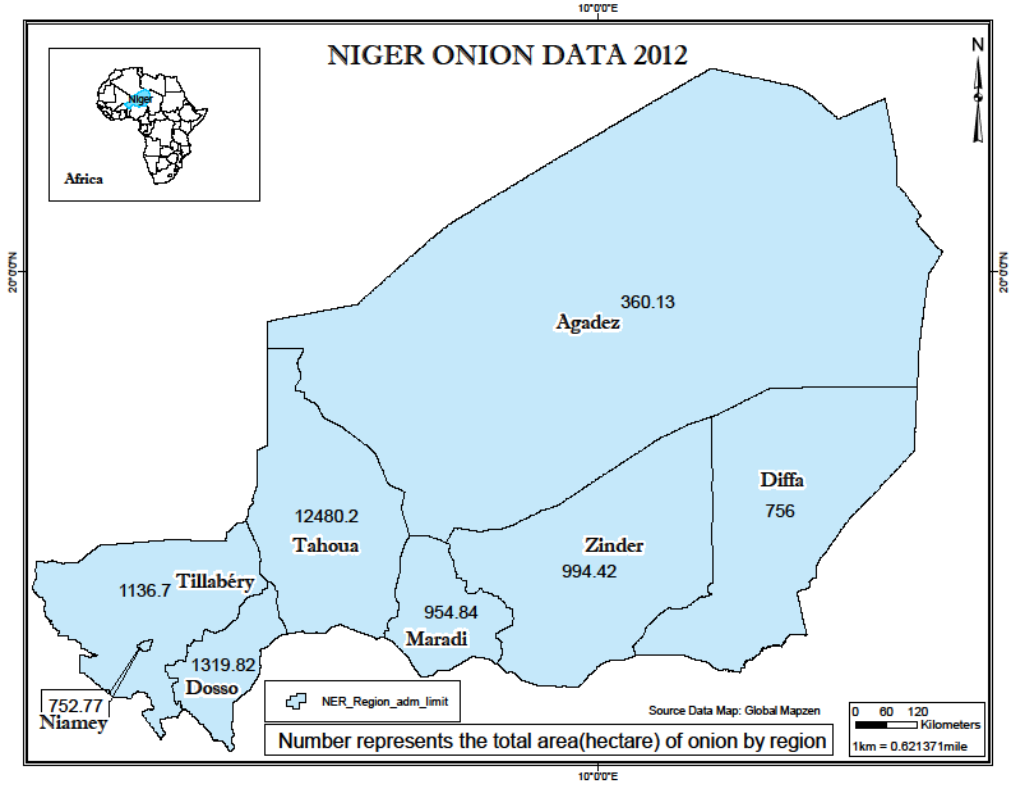

Figure 1: Regions of Niger onion data 2012

The numbers in the figure 1 represent for each region the cultivable estimated areas of onion in Niger in 2012. In general, agriculture remains the primary economic activity in the Tahoua region with an area of cultivable land estimated at 3,072,265 hectares or about 28% of the total area.

Located between rainfall isohyets 300 mm to the North and 600 mm to the South (figure 2), the agricultural area of the Tahoua region is mainly composed of the departments of Birnin Konni, Madaoua, Illela and Bouza that form the complex Ader-Doutchi-Maggia-Tarka (Abdoul-Aziz et al., 2015). It is characterized by the presence of wide, shallow valleys where the cultivated land is almost nonexistent. In this area, there are two agricultural systems, the extensive rain-fed system where grain crops (millet, sorghum, Maize, etc.) are cultivated and the intensive system where irrigated crops (onion, tomato, cabbage, potatoes etc.) are grown. To improve the agricultural productivity and face shortfalls attributed to subsistence cropping, farmers engage in irrigating onions, tomatoes, and potatoes. These irrigated crops contribute significantly to improving the living conditions of the rural population. However, there is need for infrastructural support for transportation and marketing.

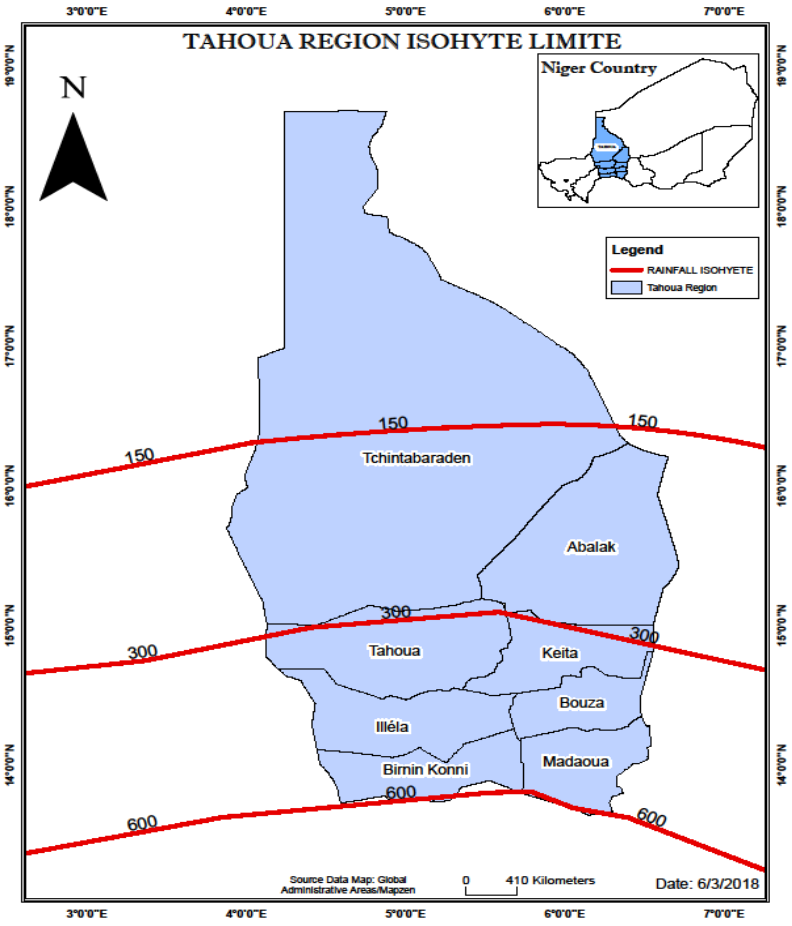

Figure 2: Tahoua rainfall isohyet

STUDY OBJECTIVES

Purpose of study

The purpose of this study is to provide a description of onion production systems in Tahoua region, Niger. The main problems follow below:

A. The development of Niger's economy involves improving agricultural production through crop diversification mainly with irrigation.

B. Because of weather conditions characterized by spatial and temporal distribution of irregular rainfall, the rain fed crops have failed to meet the food needs of the local population (O. David, 1996).

C. To improve agricultural production and to face grain (Millet, Maize and Sorghum) crop shortages, farmers engage in irrigated agriculture, which has contributed to the growth of the national economy.

D. The main irrigated crops cultivated in Niger include onions, tomatoes, peanuts, carrots, cabbage, sweet potatoes, watermelon and lettuce. However, in some areas, for example the Department of Keita, the volume of irrigated crops has declined with the collapse of its dam in 1978, resulting in lowering of the water table. In 2006 the cropping area was 4,184 hectares. Onions, the main irrigated crop, are cultivated in almost all regions of the country: Tahoua, Tillaberi, Agadez, Maradi, Diffa, Niamey and Dosso (figure 5). The total cultivated area is estimated at 20,000 hectares (MDA, 2007). Tahoua is the largest production region and produces one crop in the rainy season and one irrigated crop during the dry season. The total annual cultivated area of Niger was 18,754.88 hectares in 2012-2013 (Ministry of Agricultural, 2013). Onions are very well represented in the region of Tahoua with its most common variety, Violet de Galmi. This variety remains a high-quality product known and appreciated by consumers in many countries in Africa and Europe, exceeding competition from several other countries. Market traders, inside and outside of the region, are interested in the export of Violet de Galmi to international markets (Bruxelles, CSA, 2011). But this agriculture meets some major constraints linked to the techniques of production, and the infrastructure for transportation, marketing and commercialization. The onion is one of the main crops that contributes to the development of economic activities in the Tahoua region.

The distance between the place of production and the centers of consumption has enabled a certain number of Nigerians to create marketing networks ensuring the supply of markets throughout the year. In this study, I would like to provide a full description of onion production and irrigation systems in Tahoua Region. The GIS application is very important in this study because it is used for spatial analysis of onion collection to map the regions of farming and to show the dispersion of Niger's onions. I will conclude by providing a recommendation for improving the onion farming system and use a location allocation model to find the optimum location for an onion distribution center.

Hypothesis

Does location optimization help supply onions to markets more efficiently?

How will rearranging market centers (nodes) in the network improve supply efficiently?

Geography of Niger

Niger is a landlocked country in west Africa, at 700 km from the Atlantic Ocean. It is located between 11° 37’ and 23° north and between 0°06’ and 16° east. It is bordered to the north by Algeria and Libya, to the east by Chad, to the south by Nigeria and Benin, to the west by Burkina Faso and to the northwest by Mali (figure 3). Niger covers an area of 1,267,000 square km (Samuel, 1997) of which 75% is in the Sahara Desert. It is characterized by extreme weather conditions, poor soil and increasing desertification. It is only in the South that rainfall is sufficient for agricultural activities, however, the agricultural production fails at times to provide enough food to feed the population.

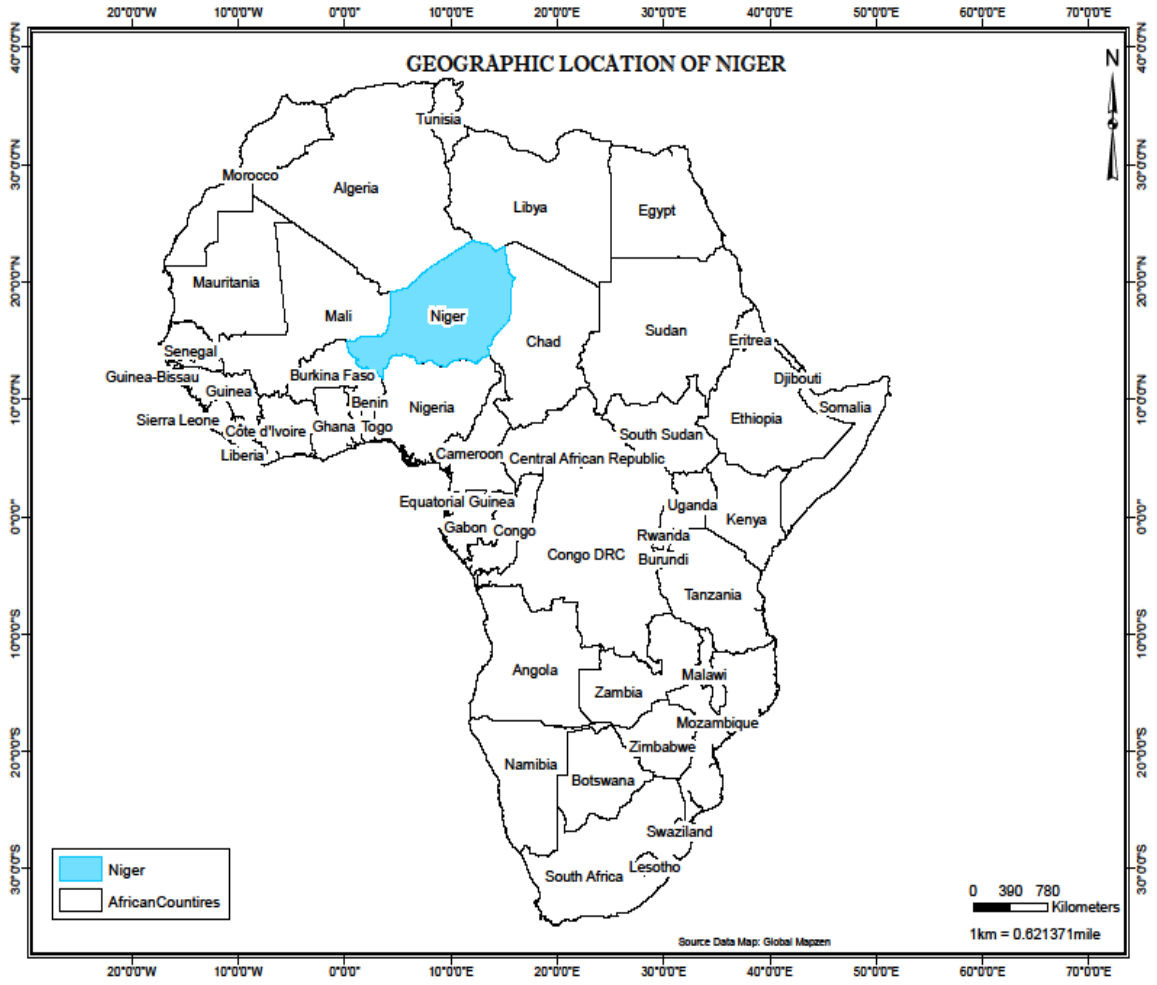

Figure 3: Map of Africa showing the location of Niger

Niger's capital is Niamey and French is the official language (Mallam Garba, 2004). The population is composed of different sociolinguistic groups, including Hausa (47.2%), Zarma (18.2%), Peuls (8.3%), Songai (5.2%), Touaregs (4.6%), Kanouri (4.2%), Arab (3.4%), Mossi (0.9%) and Dendi (0.5) (Bamgbose, 1999). According to Niger Demographic and Health Survey and Multiple Indicators, almost all of Niger's population is Muslim (99%). The Christians represent less than one percent (0.8%) and the other religions 0.2% of the population. Niger's population is unequally distributed across the eight regions, and the most populous are in the south, Maradi (19.8%), Zinder (18.5%), Tahoua (17.4%) and Tillabéry (16.3%), (Statistique (INS), Finances, & International, 2013).

Niger is characterized by a tropical climate of the Sudanese type that alternates a long dry season from October to May and a short rainy season from June to September (THE WORLD BANK, 2010). It is one of the hottest regions of the globe. The highest average temperatures are recorded between March and April when they exceed 40 °C (104°F), and the lowest from December to February when they can fall below 10 °C (50°F). The territory is divided into four climatic zones (see figure 4):

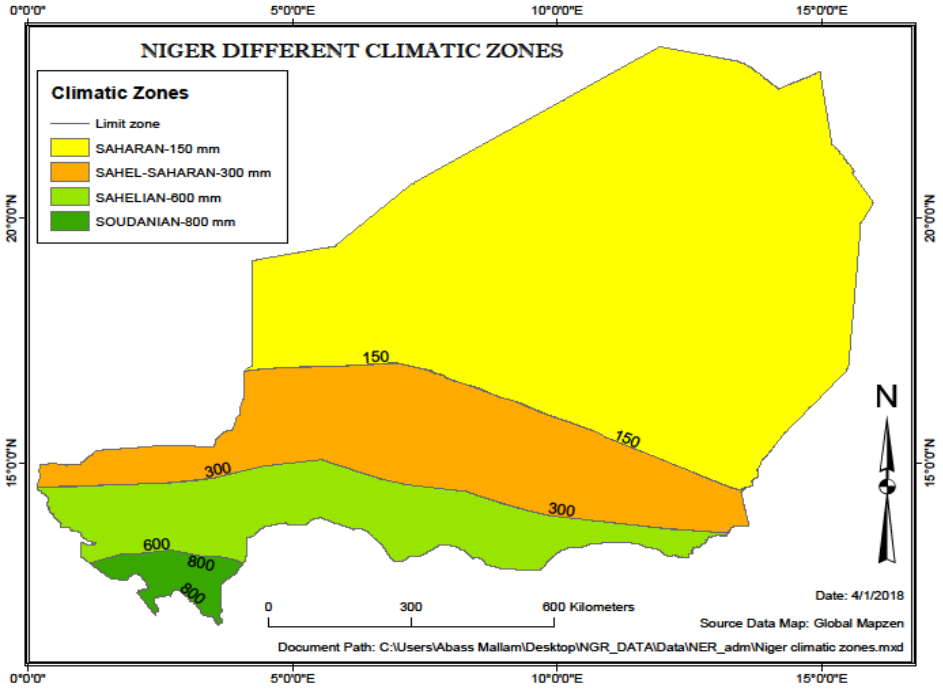

Figure 4: Map of Niger climatic zone

★ In the north, the Saharan zone reaches 150 mm annual precipitation which covers three-fifths of the country and contains no agriculture, but does invest in the mining of minerals uranium, cement, coal and gold.

★ In the center is the Sahel-saharan zone which receives an annual average rainfall of 150 to 300 mm.

★ The Sahelian zone in the south which covers 10% of Niger's total area, receives an annual precipitation of 300 to 600 mm.

★ In the south, 1% of Niger's area, a Sudanian zone receives the most rainfall in the country, with an average of 600 to 800 mm per year. It is an agricultural zone characterized by a Savanna climate and it is mainly devoted to millet, sorghum, maize and peanut crops.

Niger is divided into eight administrative regions: Agadez, Diffa, Dosso, Maradi, Niamey, Tahoua, Tillabery and Zinder (figure 5). Each region is further divided into departments.

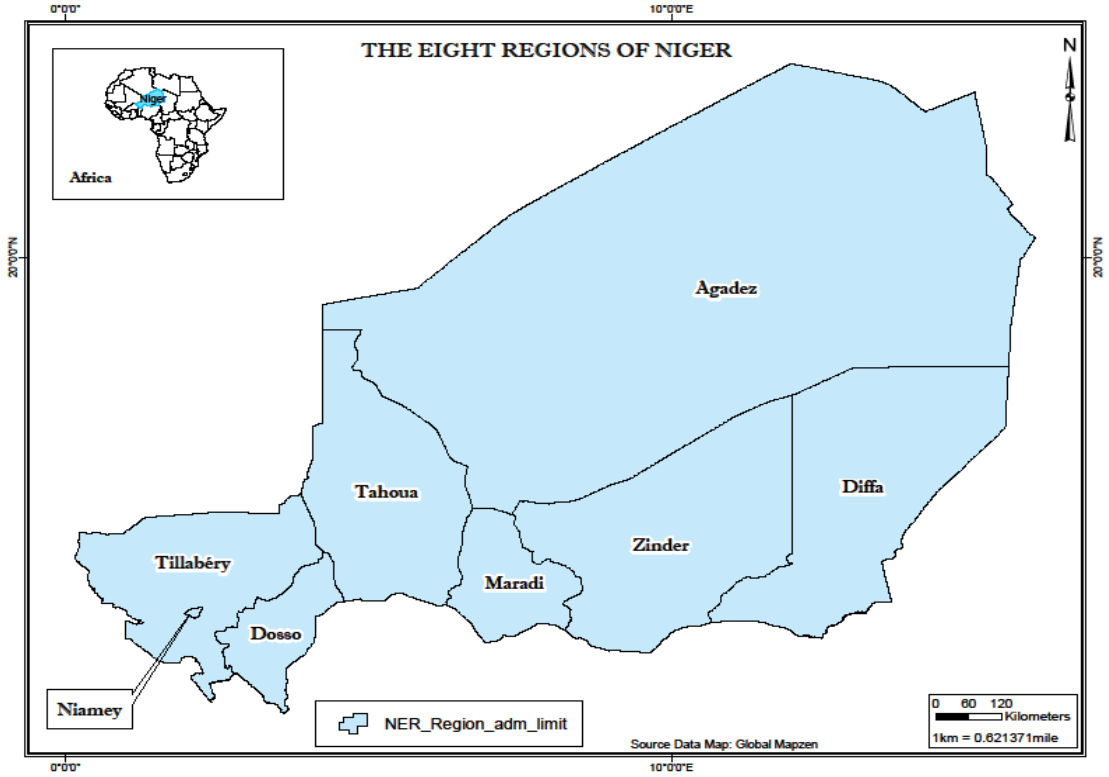

Figure 5: The eight regions of Niger

Demography of Niger

According to the general census of 2012 (table 1), Niger's population is estimated at 17,129,076 inhabitants with an average density of 13.5 inhabitants per square kilometer (Statistique (INS) et al., 2013). Niger completes its census every 10 years while to the United Nation, estimated the population of Niger is 22,311,375 on July 1, 2018. (Utazi et al., 2018).

However, this population is unequally distributed among the eight administrative regions of the country (Salifou & technique (Paris), 1989). Agadez is the largest region and occupies 53% of the national territory but contains only 0.8% of the total population. Niamey, the smallest region, is home to 37% of the population. The population growth remains high and the rate increased from 3.3% for the period 1988-2001 to 3.9% for the period 2001-2012. The factors that explain this strong growth of the population are: a significant drop of the mortality rate of children, a high level of fertility, better health coverage and the massive return of migrants from other countries (Mali, Libya, Ivory Coast, and Nigeria etc.) (Statistique (INS) et al., 2013).

Region	Population	%	Area (km²)	Density (%)
Agadez	511,188	3.2	667,799	0.8
Diffa	489,531	3.1	156,906	3.1
Dosso	2,078,339	13.2	33,844	61.14
Maradi	3,117,810	19.8	41,796	74.6
Tahoua	2,741,922	17.4	113,371	24.2
Tillabéry	2,572,125	16.3	97,251	26.4
Zinder	2,916,929	18.5	155,778	18.7
Niamey	1,302,910	8.2	255	5.109
Total 2012	15,730,754	100	1,267,000	214.049

Table 1: Census data Niger population 2012

History

Niger territory was conquered and occupied by the French between 1897 and 1900, despite the resistance of the local population. In 1900, they made Niger a military territory administered by the former Sultanate of Zinder. French became the administrative language of the country. Niger became a French colony in 1922. The capital was moved again from Zinder to Niamey in 1926.

Niger became independent on August 3rd, 1960 and Diori Hamani (1960-1974) was elected president by the National Assembly, under a single party. Accused of corruption and incapacity in the management of relief (Salifou & technique (Paris), 1989), President Diori Hamani was overthrown by a military coup in April 1974. It was then that Lieutenant-Colonel Seyni Kountché took over the regime which he converted to a military regime. His program focused on economic recovery and the pursuit of cooperation with France, particularly in terms of uranium mining. In November 1987, the president Senyni Kountche passed away and the Colonel Ali Seybou took control of the country to become president in 1989 after civilians voted for a new constitution that brought civilians back to power.

On March 27, 1993, during the first democratic election, Mahamane Ousmane was elected President of the Republic, but was overthrown by a coup on January 27, 1996 led by Colonel Ibrahim Baré Maïnassara. In April 1999, President Maïnassara, was assassinated by soldiers on the airfield of Niamey because of his refusal to have any dialogue with the opposition. His successor, Commander Daouda Mallam Wanké, chief of the Presidential Guard, described Maïnassara's death as an "unfortunate accident", and was named president by a national reconciliation council composed entirely of military officers.

The elections of November 1999 gave the presidency to the retired colonel Mamadou Tandja who led the country until 2010. On February 18, 2010, the president Tandja was overthrown by a military coup. Salou Djibo the leader of the coup took control of Niger from 2010-2011 as President of the Supreme Council for the Restoration of Democracy. He transmitted the presidency on April 7th, 2011 to the newly elected President of the Republic, Mahamadou Issoufou. Since Niger became independent from France in 1960 to the present day there have been a total of nine people who have served as head of state.

STUDY AREA BACKGROUND

Geography of Tahoua region

The Region of Tahoua was created by law number 98-31 of September 14, 1998 to determine its limits (Funel, 1976). It is located between the following parallels and meridians:

- ★ 13° 42’ and 18°30’ latitude North
- ★ 3° 6’ and 6°42’ longitude East

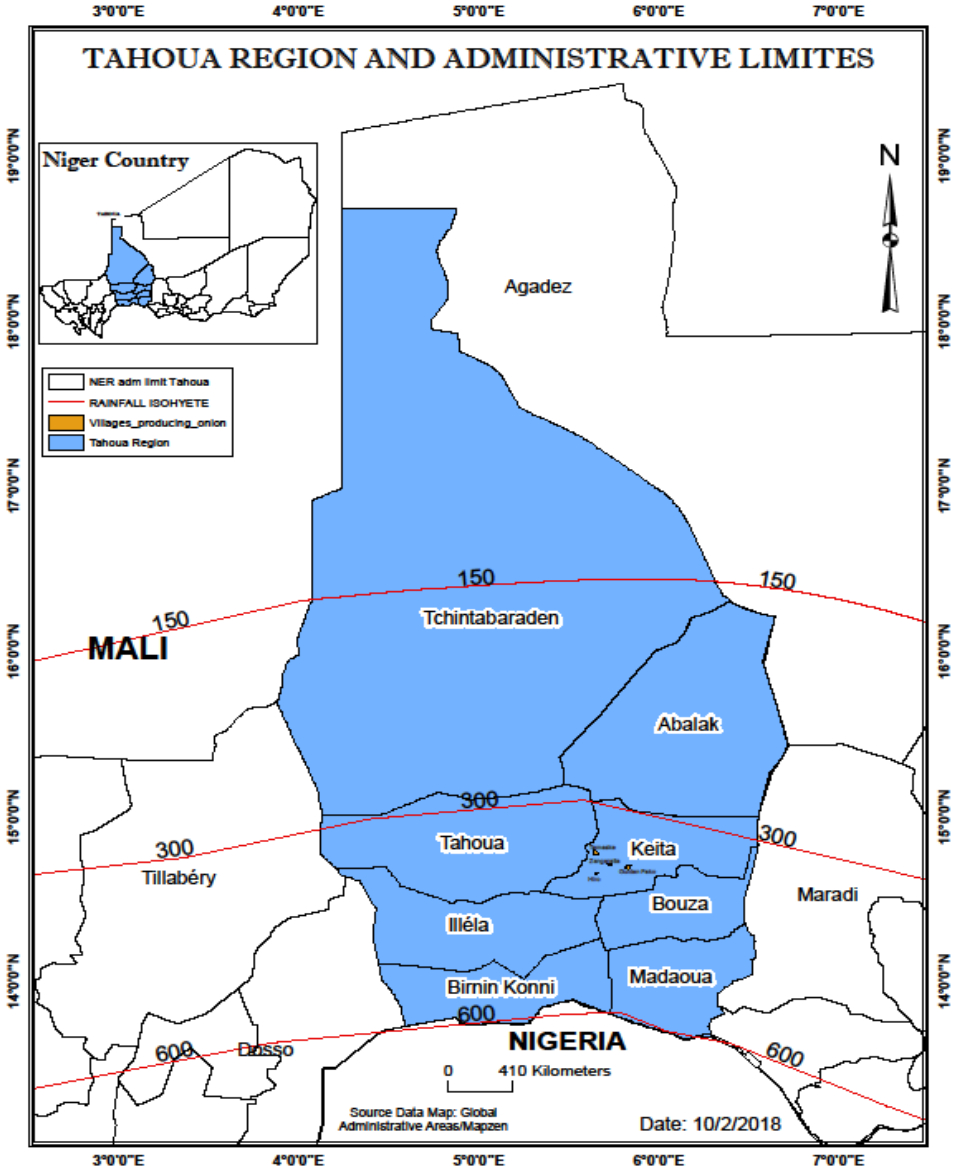

Figure 6: Map of Tahoua region and administrative limit

Tahoua region has an area of 113,371 square km and it represents 8.95% of the national territory (Aziz Abdoul et al., 2015). The region is delimited in the north by the region of Agadez, in the south by the Republic of Nigeria, in the east by the region of Maradi, in the north west by the Mali Republic, in the west by the regions of Dosso and Tillabery (figure 6). The Tahoua region is subdivided into eight departments Abalak, Birnin Konni, Bouza, Illéla, Keita, Madaoua, Tahoua and Tchintabaraden. In general regions in Niger correspond to states in US Census and departments correspond to counties.

It is a region crossed by the climate zones of the Sahel and the Savannah zone between the rainfall isohyets of 300 and 600 mm. The spatial distribution of rainfall in the Tahoua region (figure 7) shows a variation of rainfall from 2010-2014 (Aziz-Abdoul et al., 2015). The rains are well marked where the highest rainfall accumulations are recorded in the departments of Madaoua, Bouza, Illela, Birnin Konni and Keita during the year 2014. However, there are other less important pluviometry between 164.9 mm and 346.1 mm recorded in the department of Abalak and Tchintabaraden. The rainfall has a definite impact on crop varieties with more rain in the South and less rain in the North. Therefore, this is a factor to be considered in growing different crops in the region.

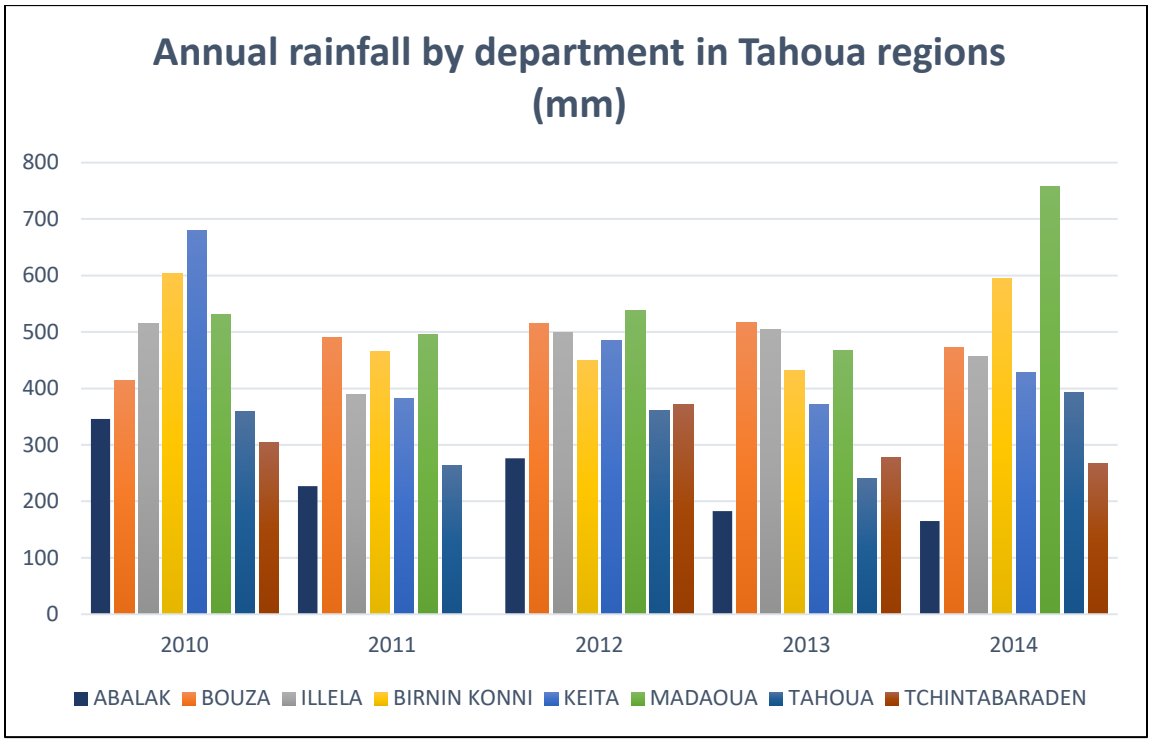

Figure 7: Rainfall region of Tahoua, **Source**: National Directorate of Meteorology of Niger.

Soils

The relief is constituted of plateaus and hills overlooking slopes bordering the fertile valleys. The geomorphology of Tahoua is composed of plateaus and fertile clay valleys. These plateaus are covered by a typical vegetation association known as the "brousse tigrée" (Tiger strips). Typical clay montmorillonite soil which shrink when dry and swells when wet dominates the region There are few water permeable soils, which accentuate runoff but also leave shallow soils that are poor in organics and nutrients. The soils are extremely compact and acidic. The valley bottoms are characterized with fertile clay soils that respond well to irrigation from ground water during the dry season. These valleys are designated as good for growing onions.

Demography of Tahoua region

According to the general census data, December 24, 2012, the population of Tahoua region was estimated at 3,328,365 habitants (Winfield, 2012). The major ethnic groups that compose the population of this region are Hausa (the majority), Tuareg and Fulani. Between 1988-2001 the average population annual growth was 3.3%. This population is distributed unequally among the eight departments of Tahoua. The most populated department is Birnin Konni with 253,879 people. The less populated department is Tchintabaraden with 84,950 inhabitants. With the census results of 2001-2012, the population of Tahoua region increased from 1,308,598 in 1988 to 1,972,907 in 2001 and finally to 2,810,716 inhabitants in 2012 (table 2). This can be explained by the growth rate of the population which passed from 3.3% for the period 1988-2001 to 3.9% for the period 2001-2012 (Statistique (INS) et al., 2013). In addition, the fertility rate and health and the education level improved.

Table 2: Census data of Tahoua region population for 1988, 2001 & 2012. Population data for by gender was not available for 1988

Total	Tchintabaraden	Tahoua	Madaoua	Keita	Illéla	Bouza	Birnin,Konni	Abalak	Department (Counties)	
1,308,598	84,950	240,184	214,025	159,675	175,080	180,805	253,879	…	Total	Population 1988
…	…	…	…	…	…	…	…	…	Male	
…	…	…	…	…	…	…	…	…	Female	
1,972,907	89,457	359,994	319,374	218,337	263,832	277,782	363,176	80,955	Total	Population 2001
986,232	45,768	174,930	162,773	105,447	131,498	138,979	185,065	41,772	Male	
986,675	43,689	185,064	156,601	112,890	131,498	138,803	178,111	39,183	Female	
2,810,716	145,086	431,823	545,538	337,098	336,621	445,363	312,886	256,301	Total	Population 2012
1,401,355	72,675	208,931	274,507	165,280	168,142	220,749	157,066	134,005	Male	
1,421,287	72,411	222,892	271,031	171,818	168,479	224,614	155,820	122,296	Female	

Methodology

The methodology used in this research is based on documentary information and field interviews with 100 onion farmers. The documentary research was done by the author at the following research centers:

1. Laboratory Documentation Center for Studies and Research on Social dynamics and Local development (LASDEL) in Niamey, Niger
2. The Regional Management for Tahoua Agricultural Development

This research links to some institutions such as the National Agricultural Institute of Research in Niger (INRAN), the National Council of Public Transport users in Niger (CNUT), the National Institute of Statistics (INS) and the Ministry of Agricultural Development.

3. The following were setup for focused examinations:

The department of Tahoua region produces more onions because they are more assessible to merchants. Some villages from the more important onion growing departments like Tamaske and Guidan Foko are faced with poor road conditions.

During field investigations, the major onion producing areas were studied at the department level. An interview questionnaire (see appendix) was given to the farmers of the selected villages to collect information about the production, the transportation and the process of onion commercialization. These interviews also provided the necessary information about the onion storage system and the market pricing. These visits to the research sites provided the information about the farmers, including data on land tenure, irrigation methods and infrastructure provided by agricultural extension agents and financial support groups.

History of Niger's onion

Onion growing as practiced in Niger has developed with the use of irrigation. According to David Olivier, its introduction probably took place in the seventh century with the roads of trans-Saharan trade (Olivier David, 1999).

Indeed, the Hausa name for the onion "Al Bassa" found its origin from the Egyptian Arabic term “bassal” or Bussul. Nevertheless, the evidence of its presence in the Tahoua region dates to the seventeenth century, with the formation of the first production center around Tamaské. The onion of Maggia, which was selected and named “Violet de Galmi’’, has a history beginning in the 17th century. The importance and the uniqueness of this crop can be attributed to the growing techniques (see pages 22-27) acquired by the farmers of this region (NDIAYE et al., 2009). In 1970, the food insecurity situation of Niger pushed the colonial regime to develop the rain fed crops; particularly the traditional cereal crops (millet, sorghum, maize, and rice) and an increasing interest in expanding the onion production area. This is what led to the formation of a second production center in the valley of Maradi region.

Niger has two seasons when irrigated onion growing is productive: The first one begins in October and extends until January. During this period, the concurrent production of onions in the neighboring countries is less competitive than that of Niger because of the climatic differences. This provides the Niger onion a huge economic advantage. The second season extends from December to March. In this cropping period, the crop productions in nearby countries such as Burkina Faso, Ghana, and Benin are the same as in Niger and provide significant competition. Among the cultivated varieties, the Violet de Galmi of Tahoua is very much in demand in West Africa and has a great competitive advantage throughout the sub-regional markets.

Supporting infrastructure for the onion

Governmental and private institutions, such as agricultural research institutions, and market information systems provide support for onion production and its marketing. The National Network of Agricultural Chambers of Niger (Niger RECA) and the markets Information System (SIMACO, 2007) help to improve the communication function in the onion sector. They also serve to circulate information on prices and stocks. The point of villager’s information (PIV) is a professional grouping center that offers information supporting onion farmers. This information represents current details for the farmers in accessing prices, inputs, inventory and transportation.

There are seven PIVs in Tahoua which produces 60% of the onion farming, two in the region of Tillabery, one each in Zinder, Maradi, Dosso, Agadez and Niamey.

There are also other partners supporting onions sector such as:

CCAIAN: Translation (Chambre de Commerce, d'Agriculture, d'Industrie et d'Artisanat du Niger), Chamber of Commerce, Agriculture, Industry and Crafts of Niger

ANIPEX: Translation (Agence Nigérienne pour la promotion des exportations), Nigerien Agency for Export Promotion

ANPIP: Translation (Association nigérienne de promotion de l'irrigation privée), Niger Association for the Promotion of Private Irrigation

ANFO: Translation (Association Nationale des Professionnels de la filière Oignon du Niger), National Association for Onion Professionals sector of Niger (2004).

There is a growing awareness of the actors in the region with the creation of different organizations in which many people are interested. Unfortunately, there are some leadership problems hindering the effectiveness of these organizations. Some village chiefs are at the same time producers, sellers and exporters of onions. This weakens the price negotiating power of the poorer villagers

Distribution centers of onion collection sites

Main production regions

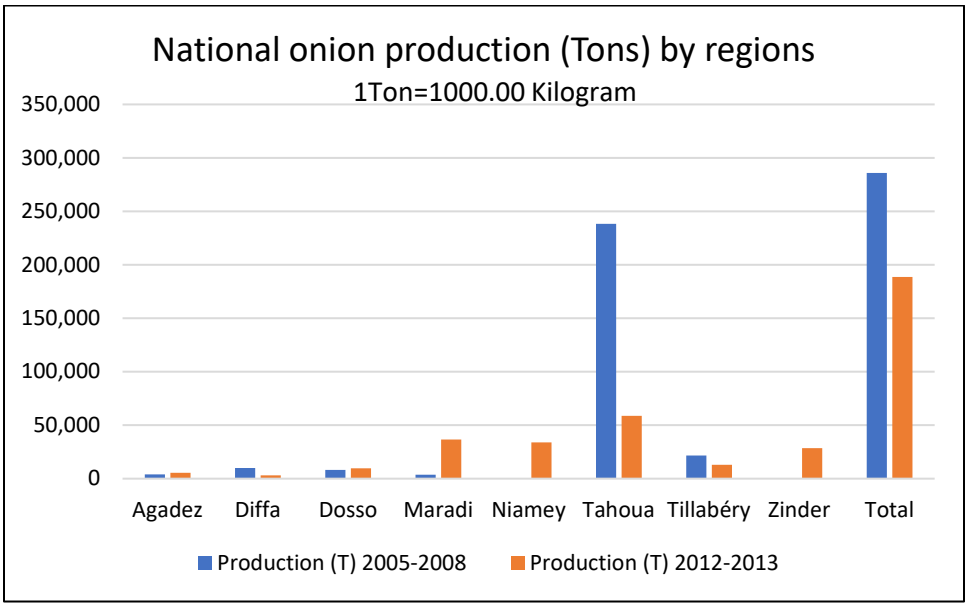

Figure 8: National onion production 2012-2013 / 2012-2013 of regions of Niger

Onion is an irrigated crop grown in all regions of Niger but varies differently from area to area. The largest production is concentrated in the Tahoua region where two seasons are harvested annually, one irrigated and the other rain-fed. During the period 2005 - 2008, Tahoua represents 72% of all onions produced in Niger. In 2008 the national production of onions was 373,600 tons from an area of 19,200 hectares (Statistic (INS) et al., 2013). The national production has become 188,767.59 tons from an area 18,754.88 hectare during 2012-2013. This decrease of production and cultivated area is due to the lowering of groundwater and the methods of production. Regarding onion cultivation, all regions of Niger are good but the areas for onion cultivation varies from one region to another. Figure 8 shows that Tahoua region has the highest production of the country which represents the main production area. This is due to the willingness to develop areas favorable for onion cultivation and to the expertise of the farmers. With the large area, Tahoua has become the most significant region for growing onions in Niger.

In 2012-2013 the onion production of Tahoua achieved 58,863 tons with cultivable area of 12,480.20 hectares. The onion data during 2005-2008 were not available for Niamey and Zinder regions, figure 8 shows that there are some other important production areas such as Diffa, Dosso and Tillabéry regions. Agadez and Diffa have large areas, but they have less production than the other regions. This means that the production may not only depend on the area favorable for onion cultivation, but it is linked to the methods of production and the expertise from generation to generation. On the other hand, the national production 2005-2008 was much better than the one in 2012-2013. The production is declining although Tahoua is still the largest producing region in Niger. The onion production over the four years is not the same around the national territory (figure 8). Onion crop is concentrated mainly in Tahoua region with 238,240 tons. The remaining territories only produce 47,614 tons. The production is provided by individual producers who benefit from the support of some actors who support the onion production.

Description of onion production in Tahoua

Agriculture is the main economic activity of Tahoua region occupying more than 90% of the population. In Tahoua region the land tenure is acquired through inheritance (70%), purchase (10%) and rental (20%).

The major irrigated crops of Tahoua region are, in order of importance; onion, tomato, potato, sweet potato, cassava, watermelon and lettuce.

Most of the production is destined for sale. Income from onions is used for paying taxes, social spending and the purchase of livestock (cattle, goats, and sheep). The development of the onion sector in Tahoua region is essential for food security, but also for generating tax revenues for the Departments. Onion production provides an overall safety-net with respect to the economy of the region.

Environmentally, the main constraints are particularly important with respect to several elements such as soil erosion, inadequate rainfall, and attacks by crops pests. Added to this, there are difficulties in accessing pesticides, improved seeds and irrigation water. The cultivation of the onion has a long history in the Tahoua region. People exploited the onion before independence, especially in the communes of Keita and Tamaské. The Hausa are the first people in Niger to be interested in the culture of the onion. Although the practice is ancient, women are engaged in small scale onion culture but not large commercial farming. Traditionally women do not engage in commercial agriculture because of the difficulties and its limited resources and the purchase of inputs such as fertilizers and pesticides. This activity is emphasized and recognized for its social place in Hausa society. The local markets cannot consume all the onion production and much of it goes to Tahoua and more distant Niger. A good road is being constructed to support exchanges over longer distances.

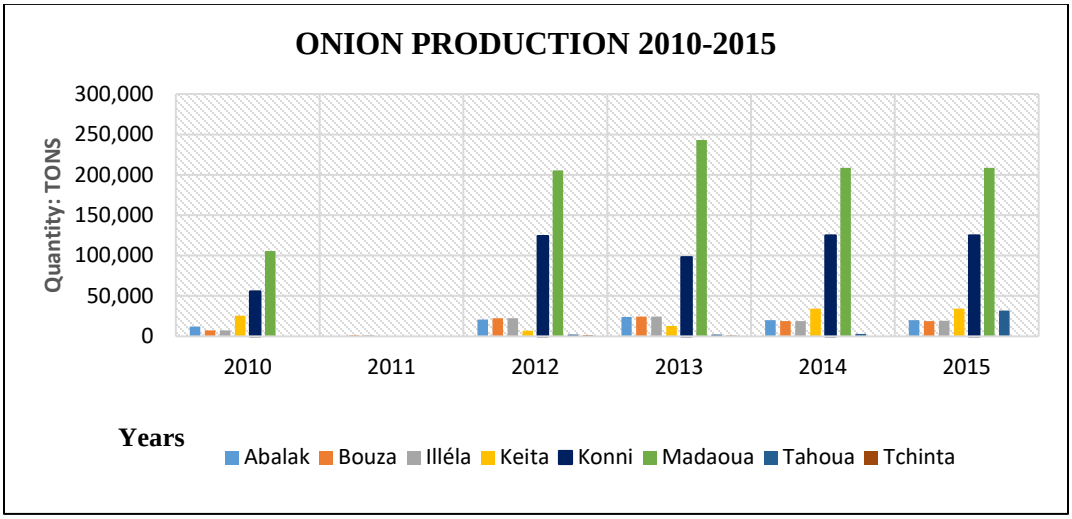

Figure 9: Tahoua onion production 2010-2015. Data were not available for 2011. **Source**: Regional Directorate for Agricultural Development of Tahoua.

Onion cultivation is concentrated mainly in Madaoua and Konni Departments from 2010-2015. This activity is a highly recognized in the Hausa society. However, there are large and small growers who produce large amounts of onions in the Departments of Keita, Bouza, Abalak, Illela and Tchintabaraden. The production was high in 2013-2014 because of higher precipitation. This was not the same in the Departments of Abalak, Tahoua and Tchintabaraden. In 2015 the weather conditions of Niger were favorable, and the highest quantity of onions were produced in Madaoua with 208,670.51 tons (figure 9).

Techniques of production

In Tahoua region, the onion fields are divided into 2-5 m^2 parcels (figure 10), some dedicated to produce seeds and others for growing onions for consumption (Ndiaye et al., 2009). Most of the farmers produce their own onion seeds based on their personal expertise. The purchase of onion seed is rare even though the seeds are available in the shops in some markets. The purchase of the seed is avoided, and great care is taken to preserve the genetic purity of the local seed which would otherwise be diluted with seeds from the market. Only a few onion farmers buy germinated seeds from the plant nurseries and replant them on their farm. The cost of these seedlings varies depending on the size of the parcel. The seed producers give credit to the farmers to be repaid in onion bags of 50kg or 150kg. The survey shows that farmers are well known for this practice. The discussions with the farmers of the department of Keita indicate that the seed pods are selected from those preserved in a traditional shelter named Rudu (figure 11) with a deferred sales payment following five to six months of storage.

Figure 10: Irrigation parcels of onion in Keita, Tahoua/Niger

Figure 11: Rudu (Traditional storage of onions: structures are made of millet stalks) in the commune of Zangaratta, Keita, Tahoua/Niger

The onion bulbs are generally chosen according to the following criteria: absence of early sprouting, an average weight, and a violet color indicating good capacity to be stored up to 6 months. The bulbs selected must not have flowered the first year and have an average weight of about 150g. After sorting, the one-inch diameter bulbs are cut crosswise into two parts: the bottom part of the bulb, which will become the root is planted, and the top portion is consumed by farm families. This traditional transplant technique by these farmers is based on the practice where the bottom half of the bulbs grow to become seed onions. Once planted, it takes forty days to produce seeds (figure 12). These plants produce yellow flowers garnished with seeds. These in turn transition from yellow to black, showing that the seeds have reached maturity. The stems holding the black seeds are cut, hung on a hanger facing the sun until they become dry. Once they are dry, they are processed with a mortar and pestle to be transferred to a dry location and stored in cotton bags for up to a few months before planting.

Figure 12: Onion seed production, Keita/Tahoua

Transplantation system

In Tahoua region, a few farmers purchase onion sprouts grown in another farmers nursery while most farmers transplant their personal nursery. The nursery is planted in mid-October; however, some farmers prepare their nurseries in September at the end of the rainy season, planting in dry places to prevent excess water from damaging the young plants. The gap, 15- to 20 cm between transplanted bulbs provides high-caliber onions, greater than or equal to 50g. When transplanted with approximately 10 cm, the bulbs are able to grow to an average size of 50g which is preferred by the traders for better preservation during transport. The bulbs transplanted early in the first season are for an early harvest.

Figure 13: Transplantation system

Sections transplanted early in the first season (October-January) are for an early harvest in 2010 (figure 13). Seven-centimeter-high soil ridges are constructed to hold irrigation water that soaks the young onion plants in the first growing season (October- January). Water is brought through the small ditch to the right and temporary cuts in the ridges allow water to flood each parcel separately for one day.

Existing varieties

According to the survey results there are several varieties of onions grown in the Tahoua region. The white and red Soumarana were introduced from Nigeria. However, the Violet de Galmi is the common local variety and is known throughout this sub-region. Consumers recognize the Violet de Galmi by its purple color and spicy flavor for which it is famous. The qualities of this variety are certainly related to the local soil, but also to the expertise of farmers that is passed down from generation to generation. The seed production system of the Violet de Galmi onion is standard for all the farmers.

The majority of the farmers produce their own seeds in the field and follow techniques that maintain the purity of the varieties. Most farmers buy seed only from farmers who have gained this expertise. This understanding reflects a high degree of trust between the farmers.

Irrigation system

With irrigation, farmers are able to regulate the production of onions. Traditional wells (figure 14a), modern wells and boreholes produce the water for growing onions (figure 14b, 14c). According to farmers, the use of the hand pumps forces them to irrigate only short distances. The hand pumps are replacing more traditional water wells where buckets are drawn to the surface with ropes from 5 meters below. Some of these wells collapse each year and need to be re-dug. In the region of Tahoua, the onion farmers use motor water pumps more than they use the manual hand pumps and animal traction systems (figure 15). The mismanagement of irrigation water by farmers and the high evaporation rates lower the level of the ground water. Because of this, there is a need to modernize the irrigation techniques to conserve water for onion production.

Figure 14a: “Moto” pump draws water from a traditional well

Figure 14b: Pipe releasing irrigation ground water in the onion field

Figure 14c: Irrigation channel distributes ground water to the separate parcels

Figure 15: Irrigation system with animal traction in Tamaske, a donkey lifts water 10 meters from a traditional well with a pulley.

These pictures show the animal traction system used to draw water from the wells for the last 40 years. A donkey pulls the rope to bring the water bucket from the well. The water is poured into a channel connecting to the onion field.

The harvest

After 120 to 150 days of planting, normally in December the onion farmers dig up bulbs with great care to avoid bruising (figure 16). The onions leaves are cut to cover the harvested bulbs which are left drying in the field for 4 to 10 days for partial dehydration. Then, the onions remain stored in one place and are covered with the same leaves to protect them from the sun. Because of the two onion harvest cycles, the department of Keita is unique from the surrounding regions. The onions harvested in the first cycle are marketed directly to wholesalers who export directly to neighboring countries. The second harvest in March, the onions are stored temporarily until the price get high.

Figure 16: Careful onion harvest at Tamaské/Keita/Tahoua

Commercialization

Marketing involves several actors: merchant-exporters, importers and other actors in the onion sector (Terpend, 2006). The distribution circuits come in various forms ranging from the relationship between the producer and the consumer through many intermediaries. In general, the marketing of onions takes a long circuit containing many actors. Most often family relationships play an important role in the marketing network between producers, intermediaries, retailers and transporters.

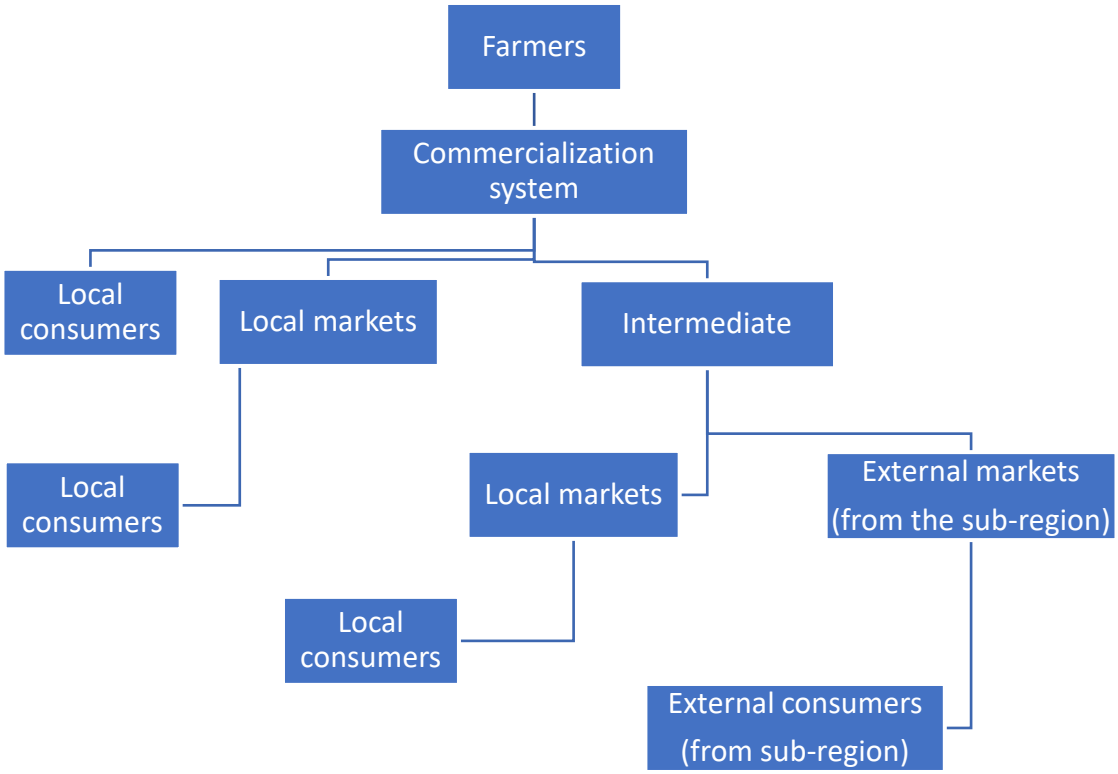

Figure 17: The marketing distribution network of Niger onions

Moreover, depending on the degree of trust, the farmers give their harvest to the Nigerien traders who are responsible for export. The traders pay money to the farmer once they return from selling the onions. The intermediaries inform traders of the availability of onions through telephone contacts.

Their role is to collect onions; find customers; and negotiate the onion prices based on the product quality. In addition, they supervise the filling of bags (packaging), the payments and the loading. When the buyers arrive, the intermediaries inform the farmers about the price negotiated with the merchants. They also control the quality before starting to fill the onion bags.

Indeed, the purchase is done at the primary collection centers (farms) and at the secondary collection centers at the loading center. The commercialization of Niger onions can be represented by a graphic which shows the marketing distribution network (figure 17). While local consumers' diets include some onions, most of the onions are sent to external markets for consumers of the sub-region (Bruxelles, CSA, 2011).

The surveys (appendix) of the various villages show the after-harvest onion production as follows: consumption and gifts (10%), farmer's credit repayment (approximately 50%) and the cost of marketing (40%). The amount of onion for commercialization can be sold entirely at the farm (figure 20) when there is a huge need, sometimes stored, partially or totally. In the department of Keita some producers transport their onions using a cart or on the back of a camel (figure 18) from the field to a storage place, or from a village to the distribution center (figure 19) and the rates vary depending on the distance.

Figure 18: Onion transportation system to the loading place.

Figure 19: Onion loading point at Keita/Tahoua

In some localities of the Tahoua region such as Zangaratta, and Hiro, the pricing system fails. Villagers determine the price of their onions regardless of price quoted in the national radio. The sale is still personal despite the presence of professional organizations, and the transaction takes place between producers and intermediaries. Small onion quantities are often purchased by women who resell them in local markets.

Figure 20: Harvested onions at the field, ready for transportation to the market. (Tamaské January 2010)

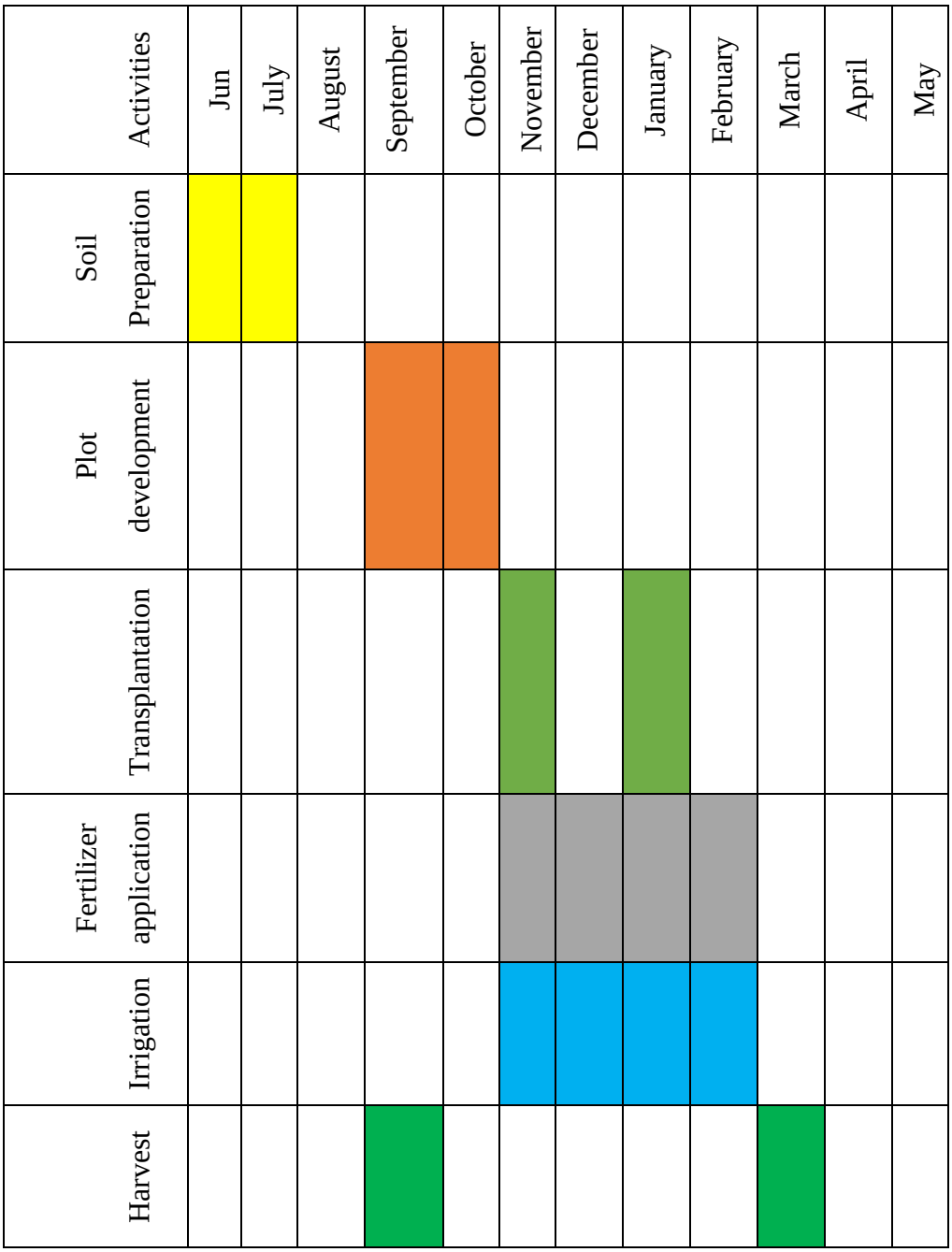

Figure 21: Calendar of onion production in Niger

As previously noted, Niger's weather conditions allow two onion production cycles:(figure 21) from September to December (first cycle) and from December to March (second cycle). Fertilization is done by using manure and imported chemical fertilizer which are marketed in supply centers privately owned through formal and informal channels.

The irrigation system is classified into two categories:

★ a traditional system, where water is hand bucketed from wells

★ a diesel pumping system from wells.

However, there is also a diesel power water sprinkle system on the large-scale farms (5-10ha).

Economic and social place of the onion

Onion production is a major component of the national economy. Onions are also consumed throughout the region, although there are significant disparities in consumption between urban and rural areas. Rural farmers are more interested in the money for investing in other foods or personal necessities while the urbanists consume onions at a higher rate. Onions are consumed during the whole year for the preparation of sauces, except in some areas where they are part of the traditional eating habits. The unit costs of production in the countries of the sub region vary according to the soil type, climate, and the economic conditions in which farmers operate. They influence both yields and the factors of production including quality, quantity and price of labor and inputs. Consideration should be given to the costs of different means of transportation, which help to establish the competitive capacity of the various production areas in the consuming markets.

The region of Tahoua has fertile valleys favorable to crop production that generate revenue contributing to the strategy of reducing poverty. West African countries produce a variety of onions. However, Niger is the country that exports significant surplus onions throughout the region. An opportunity for exchange between these countries derives from the gap between supply and demand throughout the sub region. Ivory Coast, Ghana, Benin, and Togo have significant onion demand that cannot be met by their own production. The onion most wanted by sub-regional consumers is Violet de Galmi of which Niger remains the main supplier(Bruxelles, CSA, 2011).

Physical flow of onion

In west Africa, the onion market is very important. This fact is highlighted by the increase in production and consumption in recent years. The onion of Niger dominates the market of the sub region during a certain period.There are many countries importing onions from Niger to meet the domestic need of their population (figure 22).

According to FAOSTAT, in 2008 Niger exported 50,184 tons of onions. Demand for onions in west Africa is very high which is what increases the volume of exports (figure 23). The Ivory Coast and Ghana markets are the most likely countries to increase their imports of onions from Niger. Other countries such as Algeria, Benin, Burkina Faso, Guinea, Nigeria, and Togo are importing very small quantities of onions from Niger (Bruxelles, CSA, 2011) because their markets are often supplied from Europe (Holland). Niger remains the main supplier to countries in the sub-region (Winfield, 2012). In addition, the "Violet de Galmi" is periodically challenged by white onion varieties imported from Europe (Holland) to the level of the sub-region markets.

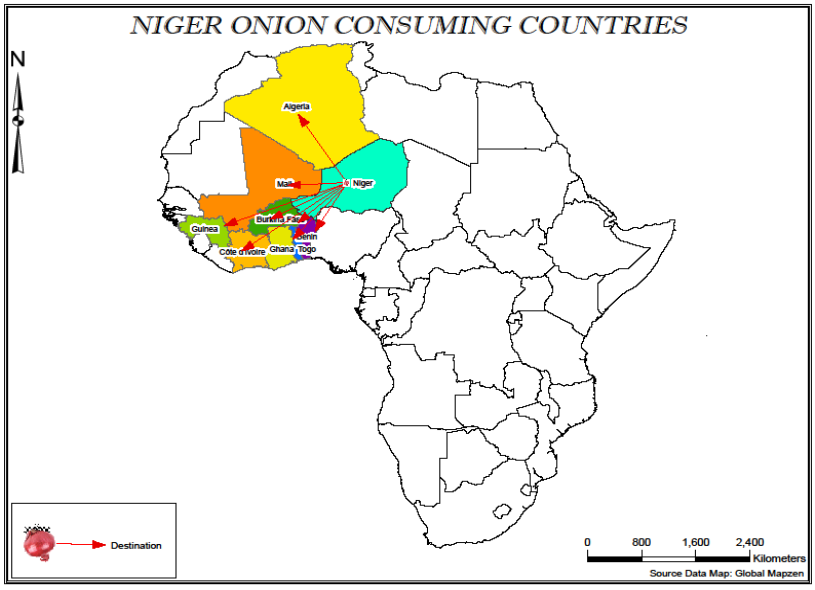

Figure 22**:** Map of Niger Onion consuming countries. **Source**: FAOSTAT, 2008

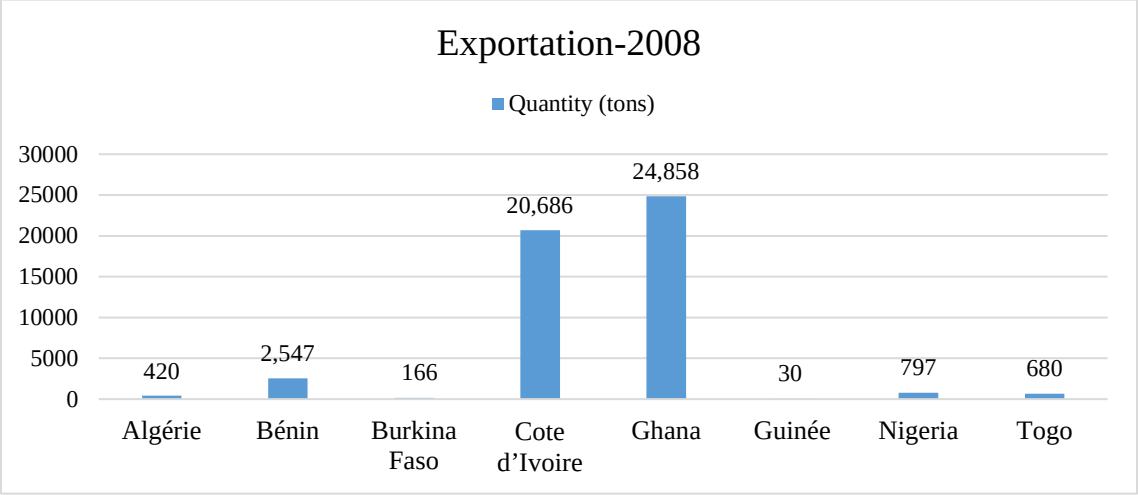

Figure 23: Onion exports by west African. **Source**: FAOSTAT, 2008.

Location allocation

With scientific advances, facility location problems became a branch of optimization (Tafazzoli & Mozafari, 2009). The objective of this study is to minimize the transportation cost by identifying the optimal locations of onion distribution centers and to find the best locations to sell all onion production. Previously, the different departments of Tahoua region had an original location for distribution centers (data is not available) based on tradition that facilitated access to the loading points for the trucks. Unfortunately, those loading points were chosen without any location optimization considerations. Mathematically, the transport cost increased for all demand points which intern added to the cost for all the actors involving (famers, buyers and seller) in the sector.

A total of 8 facilities are needed to cover all 202 demand nodes with an average minimum distance of 230.8 km. figure 24 shows the proposal collection sites that would minimize travel expenses from all the demand points. The classification of facility location is based on optimizing the decisions to locate facilities to minimize the variable costs and maximize the assignment for customers (Masudin, 2013). The customers are the most important consideration in selecting facility location regarding minimize their transportation costs. It means that the location-allocation analysis tools using GIS makes it possible to determine the best locations to reach for each department of Tahoua region if the onion gets the same price of production everywhere in Tahoua region. The chosen facilities represent the optimal places where the intermediaries in charge of onion export would also benefit with the minimization of their transportation cost.

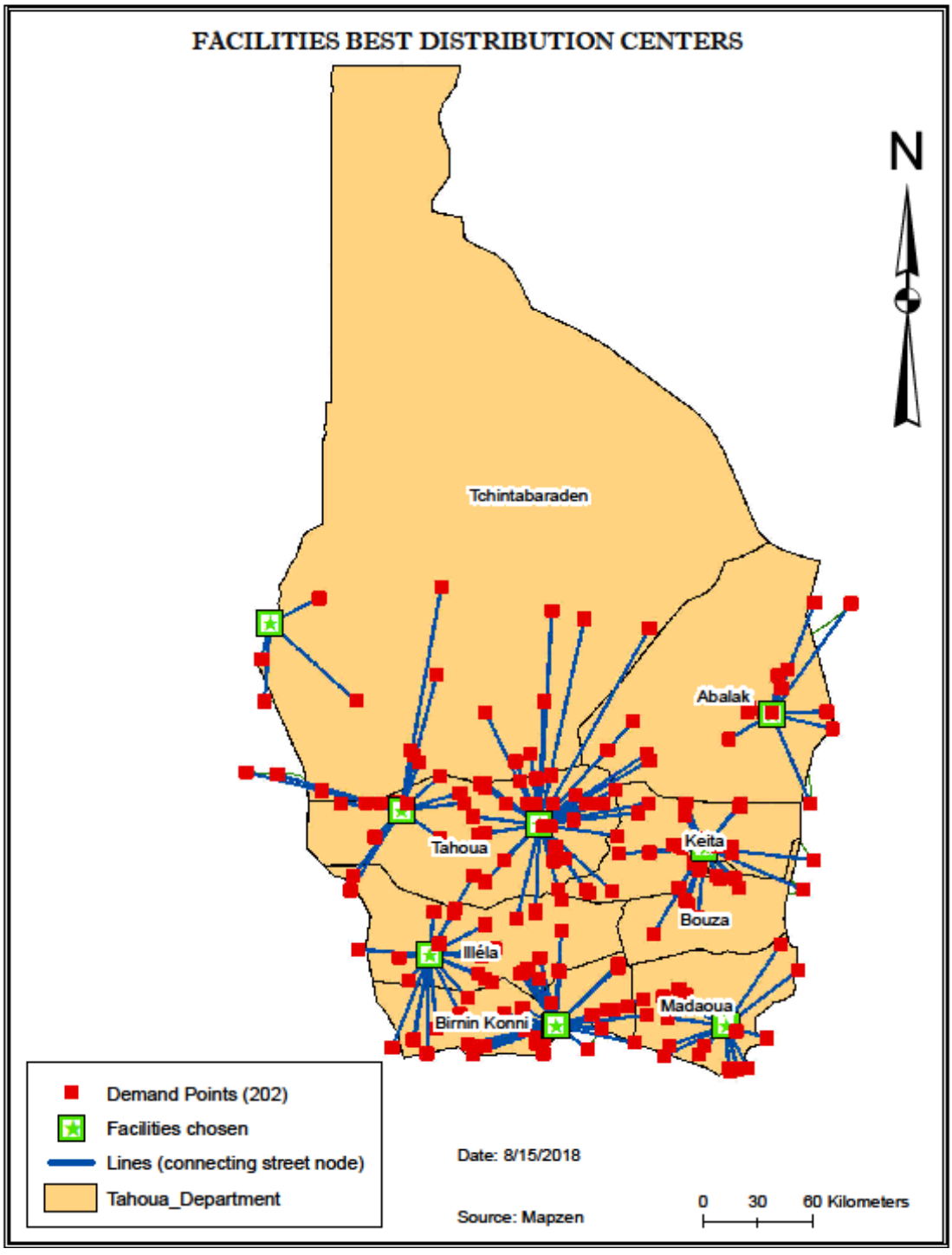

Figure 24: Eight facilities covered all demands in 230.8 km.

Object ID	Name Location	Weight	Demand Count	Source OID	Total Length (Km)
4	Tchintabraden	1	5	27	230.8
20	Tahoua	1	22	56	949.4
29	Illela	1	25	39	925.6
88	Tahoua	1	51	69	2274.9
102	Birnin Konni	1	35	2	1280.8
162	Keita	1	28	79	820.3
169	Madaoua	1	20	3	574.9
189	Abalak	1	16	222	437.9

Table 3: Locational component

Table 3 shows that, a facility location type, is chosen within the locational of the demand points count. Data on the specific locations of the distribution centers for the different departments of Tahoua region were not available. Instead, eight random road intersections designated for distribution centers were selected in the departments of Tahoua region to establish the facilities location model. The location allocation model for this analysis demonstrates the possibility of GIS modeling for the other intersections. The chosen facilities locations are measured by the distance of the demand counts. The intersections points have a distance calculated in kilometers. The maximum distance to cover the largest demand points of 51 counts is 2274.9 km with a total mean distance of 936.8 km for all 202 demand points.

Facility location models have an advantage to be considered when an economic activity is taken place in geography (Fearon, 2002). In a location problem, the distance between facilities has a significant role to determinate optimal locations that minimizes the distance impediment. The distance between the chosen facilities and the demand points is defined as the length of the path of those facilities (Masudin, 2013). In table 3 for example, the chosen location 4 has 5 demands points with a total length (distance) of 230.8 km. The formulation of the location models has been developed and illustrated (Toregas & ReVelle, 1972) as follows:

$$\text{Min} \quad \sum_{j \in J} xj$$

$$\sum_{j \in Ni} xj \geq 1 \qquad \forall\, i \in I$$

$$xj \in \{0, 1\} \qquad \forall\, j \in J$$

Where,

I = to the set of demand nodes

J = to the set of candidate locations

Ni = to the set of all candidate sites which can cover demand node i

xj = 1 if we locate at candidate site j and 0 otherwise

This function was assigned to minimize the number of facilities needed to cover all demands. The maximal covering locates facilities which can maximize the number of covered demands (R. Church & ReVelle, 1974). The maximal covering can be formulated as follows:

$$\text{Max} \quad \sum_{i \in I} hiZi$$

$$\sum_{j \in J} xj = P$$

$$Zi - \sum xj \leq 0 \qquad \forall\, i \in \qquad xj \in \{0, 1\} \qquad \forall\, j \in J$$

$$Zi \in \{0, 1\} \qquad \forall\, i \in I$$

Where;

hi = demand at node i

p = number of facilities to be located

xj = 1 if candidate located at node j = 0 otherwise

Zi = 1 if demand I covered by location j = 0 otherwise

The second function is assigned to maximize the number of covered demands.

The difference between the two coverings is in the objective functions where the purpose to minimize the number of facilities will be in the condition that each demand point has to be covered, at least, by one facility. Also, the maximal covering selects p facility to maximize the number of coverages demands (Daskin, 2008).

P-median

The P-median problem was first used by Hakimi (1964) to find medians on graph to determine a median point on the network which minimizes the sum of distance between the point and the graph's vertices (Marianov & Serra, 2009). The first methods that were proposed for solving the p-median were heuristic. Among these, (Daskin, 2008) describes heuristic that randomly locates p facilities and solves the allocation problem. The p-median problem application is widely used in public and private sector location decisions. In public sector, the p-median is used for example for hospitals, schools, fire emergency to solve a problem by minimizing the average distance between the community and the public facilities (Marianov & Serra, 2009). The works of (R. L. Church & ReVelle, 1976) proposed an optimal procedure for p-median, based on linear programming and their formulation is as follows:

P-median =

$$\text{Min} \quad \sum_{i,j} h_i d_{ij} x_{ij} \qquad (1)$$

$$\sum_{j \in j} xij = 1 \qquad i,j = 1, 2, \ldots n \qquad (2)$$

$$x_{ij} \leq y_j \qquad i,j = 1, 2, \ldots n \qquad (3)$$

$$\sum_{j \in j} yj = P \qquad (4)$$

$$x_{ij}, y_j \in \{0,1\} \qquad i,j = 1, 2, \ldots n \qquad (5)$$

Where:

i Index of demand points

j Index of potential facility sites

n Total number of potential facility locations

hi, Weight associated to each demand point.

dij Distance between demand area *i* and potential facility at *j*.

xij Variable that is equal to 1 if demand area *i* is assigned to a facility at *j*, and 0 otherwise

yj Variable that is equal to 1 if there is an open facility at *j*, and 0 otherwise. The objective function (1) minimizes the demand-weighted total distance, so each demand point to be assigned to only one facility. Constraints 2) allows each demand to be assigned. Constraints (3) limit assignments to open or selected sites. Constraint (4) states where p facilities are to be located. Finally, constraints (5) represents the binary integer model valued 0 or 1 for the decision variables (facility location candidates).

CONCLUSION AND RECOMMENDATIONS

Today, the onion is a cash crop that is experiencing significant development in Niger mainly in the Tahoua region because of the existence of its large valley favorable for onion production. This sector has been developed for coastal markets which absorb most of the production. The poor distribution of rainfall over time and space puts several departments of the region in a situation of food crop deficit. Faced with this phenomenon many farmers practice the cultivation of onions. This activity has constraints and needs strong efforts to develop. Onion marketing is hampered by the lack of dependable transportation from the farms to the markets. Once the roads have improved, the onion farming in the departments of Tahoua will be greatly enhanced. The advantages of the onion crop in the Tahoua department includes the availability of a productive variety adaptable to storage. The existence of good soils for production, the mastery of production technique, storage technic, and the development of the two seasons of production, favor a supply of Violet Galmi throughout the year for domestic and foreign markets. However, to promote the marketing, it is very important to create a packaging with more advertising and informative value and better conditions for the onion.

In addition to this, the regional department should take into consideration the allocated distribution centers because the road network analysis identifies the ideal locations serving the departments. The location of the eight distribution centers indicates the places with the highest economic demand. It is more convenient to take the onion to those distribution centers because it reduces the total cost of distance and time for the farmers.

APPENDIX

Questionnaire
Q1: Name of farmer: Location: Date: Sex: M F
Q2: Main activity a. Farmer b. Merchant c. Other
Q3: What is the onion marketing period? a. All year long b. Only in certain seasons
Q4: Do you have some collaborators? Yes, or No What is their role? Village collector b. Truck driver c. Informers
Q5: Where do you do generally sell your onion? a. Village b. Road c. Market
Q6: Where do you export the Nigerien onion?
Q7: What is the amount of onion that you sell monthly?
Q8: How much the onion bag cost?
Q9: Is there any seasonal variation? Yes, or No
Q10: How do you get information about the availability and price of onion? a. Informers b. Radio c. Newspapers d. Other

Q11: Do you store your onion before selling it?
Q12: What type of problems do you encounter in stage?
Q13: How are you organizing to transport the merchandise? a. Individual b. Collective c. Other
Q14: What are the problems related to the transportation of onion?
Road poor condition b. Unsuitable transportation c. Long distance
Q15: What are the main Nigerien market where you sell your onion?
Q16: In which countries do you export your onion?
Q17: In what period of the you export more onion?
Q18: Where do you get the onion seed?
Q19: Why do you prefer the local seed but the one in the store?

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CURRICULUM VITAE

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Education

Master of Science in Geography Information Science, 2019 at Indiana University Purdue University Indianapolis, IN

Bachelor of Science in Physical Geography, emphasis in Biogeography, 2009 at University of Niamey, Niger

Professional Experience

City of Indianapolis, Department of Public Works, August 2018-Present. Assist the Engineering team for:

- Storm water and pedestrian crash zone data
- Hydrant parking restrictions
- Storm drain marking
- Concrete pavement and join removal
- Traffic inventory

Research project on the onion cultivation and marketing in Keita Department, 2014-18

Indiana Rural Community Assistance Program August 2016 - January 2017

- Update rural community water and wastewater utilities
- Maintain and manage ArcPad for G.I.S mapping

City of Indianapolis, Department of Public Works, Intern, Spring 2016