Geograpic Studies Series (8)

Medical Geography of Sudan

Professor
Samir Mohammed Ali Hassan Alredaisy

First edition 2024 AD

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Introduction

Sudan faces many serious health and medical challenges and problems where geography could contribute to the mitigation of their impacts. Medical geography is an applied field that deals with the geography of diseases and medical services. This book is concerned with some of these issues such as the most prevalent infectious diseases of malaria, typhoid, and tuberculosis, and topics on rural and urban nutrition, arid environment and cancer, and environmental health conditions in a squatter settlement on Khartoum's periphery.

These topics on the medical geography of Sudan satisfy the objective of this book which is to review and discuss these topics as imperatively significant and important for environmental management and planning in Sudan and furthermore, to work towards alleviating their negative impacts. It is important to recommend for future writings on medical geography of Sudan by authorized researchers.

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March 2024

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Arid Environment and Rock Mineral Contents Catalyst

for Higher Vulnerability to Cancer Morbidity

in the Northern State of Sudan

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People are exposed to small amounts of radiation from radioactive elements that occur naturally in rocks and soil. Reflectivity and adsorption of radiation, particularly ultraviolet radiation by rock type and superficial deposits are effective in that. The strength of the UV rays reaching the ground depends on the time of day, season of the year, distance from the equator, altitude, clouds, reflection off surfaces, and contents of the air, and the Ozone layer which filters out some UV radiation. Mineral radioactivity is due to alpha, beta, and gamma radiation from the unstable isotopes in the composition. Thermal emittance or emissivity is the ability of a body to release heat (Akbari and Levinson, 2008). Solar reflectance index (SRI) is initially influenced by material composition, surface texture, and orientation. Solar reflectance, or albedo, is the ability of a material to reflect - rather than absorb - energy emitted from the sun (The University of Tennessee Center for Clean Products, 2009). The absorbed solar radiation by material differs according to color. It is 0.35 for light limestone, 0.50 for dark limestone, and 0.73 for red sandstone, 0.66 for dark marble, 0.55 for reddish granite, and 0.87 for blue grey slate. Many large granite plutons are sources for roll front uranium ore deposits, where the uranium washes into the sediments from the granite uplands and associated, often highly radioactive, pegmatite. Thorium occurs in all granites as well. Conway granite has been noted for its relatively high thorium concentration of 56±6 ppm.

Radon is a radioactive gas that forms naturally from the decay of radioactive elements, such as uranium, which are found in different amounts in soil and rock throughout the world. X-rays and gamma rays can come from natural sources, such as radon gas, radioactive elements in the earth. Radon breaks down into solid radioactive elements called *radon progeny* (such as polonium-218, polonium-214, and lead-214). Radon progeny can attach to dust and other particles and can be breathed into the lungs. As radon and radon progeny in the air break down, they give off radiation that can damage the DNA inside the body's cells.

The silicate minerals can be viewed as the fundamental materials out of which other rock groups, sedimentary or metamorphic, are created. The majority of igneous rocks are composed of two or more of silicate minerals with different percentage. About 99% of the bulk of igneous rocks of the earth's crust consists of the seven silicate minerals, or mineral groups :Quartz : SiO_2 ; Potassium feldspar (K, Na) $ALSi_2 iO_8$; Plagioclase Feldspar : rich in sodium ($ALSi_2 iO_8$ Na), rich in calcium (Ca AL_2 $Si_2 iO_8$); Biotite (Mica group): Aluminum silicate composed of potassium, magnesium and iron with water; Amphibole (Hornblende): Aluminum silicate composed of calcium, magnesium and iron; Pyroxene Group: Aluminum silicate composed of calcium, magnesium and iron; Olivine (Mg, Fe_2, SiO_4). Most of silicate minerals also contain one, two, or more of the metallic elements: aluminum, iron, sodium, calcium, potassium, and magnesium.

Based on percentage of SiO_2, igneous rocks are grouped into ultra mafic rocks (- 42% of SiO_2), mafic (42-52% of SiO_2), medium (52-62% of SiO_2), and acidic (62-80% of SiO_2). The Mineral composition of igneous rocks includes basic and additional mineral groups. Basic minerals include felsic or light color minerals and mafic or dark color group. Felsic group includes sodic, potash and calcic feldspar, transparent mica (muscovite) and quartz. Mafic minerals include olivine, pyroxene, amphibole, black mica (Biotite).

Sedimentary rocks are generally classified into terrigenous rocks and non-terrigenous rocks. Terrigenous rocks are composed of igneous rocks minerals due to the stability of theses minerals on earth surface. Most of silicate composing igneous rocks changes to clay minerals on earth surface except quartz. Therefore, the majority of terrigenous rocks are composed of high amounts of quartz and clayey minerals. Non terrigenous clastic rocks include chemically based and organically based sedimentary rocks. Metamorphic rocks are derived from former igneous and sedimentary or metamorphic rocks where a change in shape or chemical composition occurs.

Cancer is a major health issue and a leading cause of death worldwide, with more than 11 million cases being diagnosed every year (The International Union against Cancer, 2007). In Africa, new cancer cases are projected to nearly double to 12.8 million by the year 2030 (Boyle and Levin 2008). In Sudan, cancer incidence has been growing at an average annual rate of 0.061 over the last five decades 1967–2010 and is likely to continue to grow (Amany et al. 2015). The cancer prevalence rate per year was 5,000-7,000 among adults and 300-400 among children, with increasing tendency for adults, and male: female ratios were 1:1.18 for adults and 1.46:1 for children (Mohamed et al., no date). Esophageal cancer is the fourth most common cause of cancer in Sudanese males, and the fifth most common in females. Most skin cancers are a direct result of exposure to the UV rays in sunlight. Comparing cancer cases with population numbers of Sudanese states, Northern, River Nile and Khartoum states revealed up to 8-fold higher cancer incidence rates than Al Gedarief, Southern Darfur and Blue Nile. The other states had intermediate incidence rates (Mohamed and Jingming, no date). This work states that, arid environment and type of mineral content of rocks work together as catalyst for absorption of higher rates of solar irradiation that will inevitably increase vulnerability to cancer morbidity in the Northern State of Sudan compared to many other states in the country.

Sources of data included records of Ministry of Health and National Population-based Cancer Registry (NCR), published books on Geology of Sudan, published research executed by Geological Research Authority of Sudan; relevant data available by scientific sites on internet. Climatic data published by Sudan Meteorological Department and Sudan Encyclopedia, some published research on Research Gate and Scientific Journals, and some engineering sources for solar radiation absorbed by various materials (table 1).

Reference table (1):
Solar radiation absorbed by various materials

Surface Color	Absorb Factor - Fraction of Incident (Radiation Absorbed (approximated
White smooth surfaces	0.40 - 0.25
Grey to dark grey	0.50 - 0.40
Green, red and brown	0.70 - 0.50
Dark brown to blue	0.80 - 0.70
Dark blue to black	0.90 - 0.80

Source: Engineering Tool Box

Solar irradiation regions over the study area were distinguished based on provided Global Horizontal Irradiation, Sudan, Solar Resource Map, World Bank for the period 1994-2015 (KWh/m^2 daily totals and yearly totals). The general average of the solar absorb factor for the three major rock groups is calculated. These data are analyzed using deduction and derivational approach to conclude the results.

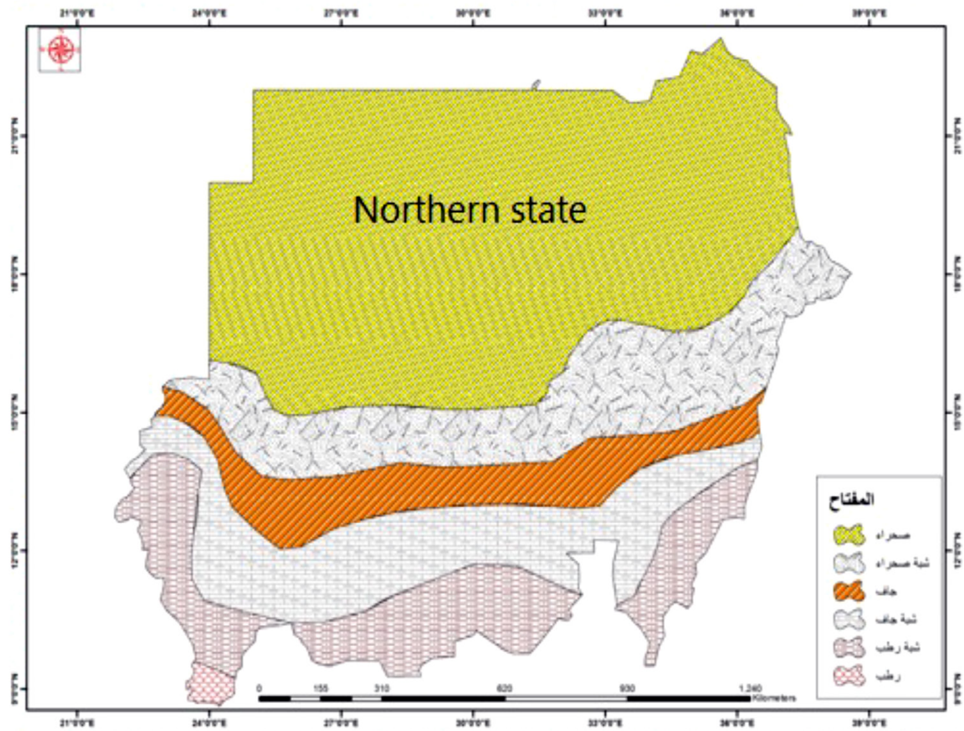
The Northern State: Location, Climate and Geology:

Northern state with an area of approximately 348,765 km^2, lies between latitudes16°N and 22°N; and longitudes 20°E and 32°E (Map 1). It is bisected by River Nile where both banks of the Nile are occupied by a total population of 699,065 inhabitants, 80% of them live in rural areas; and some others (13,964) are nomads, giving a total density of 2 persons /km^2 (2008 census).

Map 1: Administrative States of Sudan

Source: https://www.mapsland.com/africa/sudan

The northern state lies within the desert climatic region of Sudan (Map 2). The Minimum average temperature is witnessed during January which might be below 10 C ^{0}. The maximum average temperature exceeds 40 Celsius degrees during summer months of April, May, and June, July and August (Figure 1), due to absence of clouds which are the main reflection factor of solar radiation and the prevalence of dry northeast winds. Therefore, it receives the highest levels of solar irradiation over the Sudan (Map3). Annual rainfall is infrequent and ranges between 200 mm in the southern parts to 25 mm in the far northern fringe (Map 4) which means very low humidity levels and a poor sparse desert vegetative cover. The state is also under higher onsets of desertification and sand encroachment in Sudan which excavate the desert climatic conditions (Map 5).



Map (2): Climatic regions of Sudan. Source:

Source: sudapedia.sd/ar/content/136

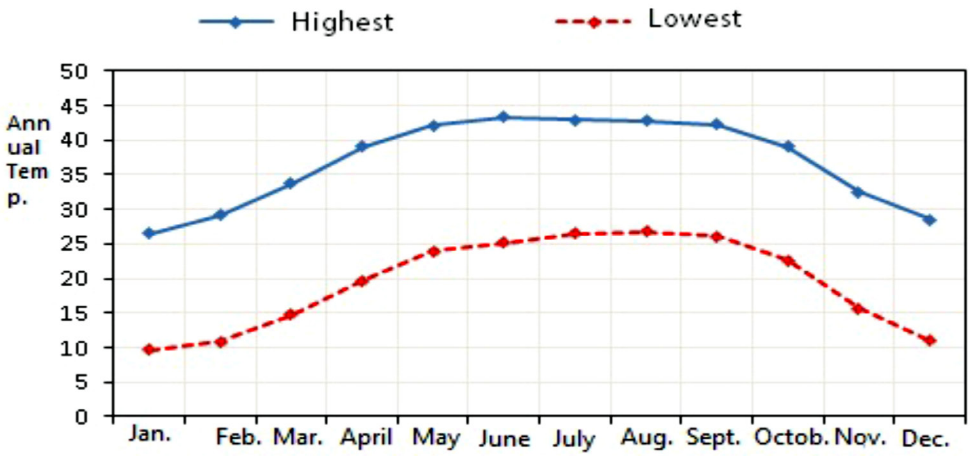
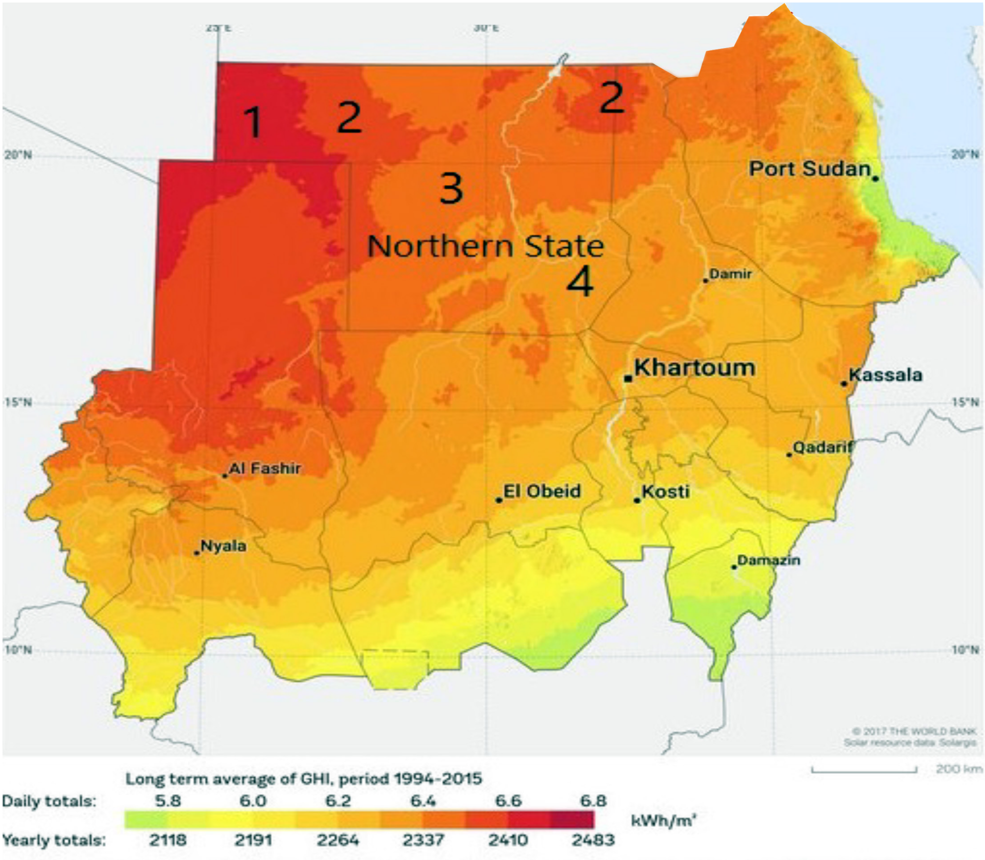
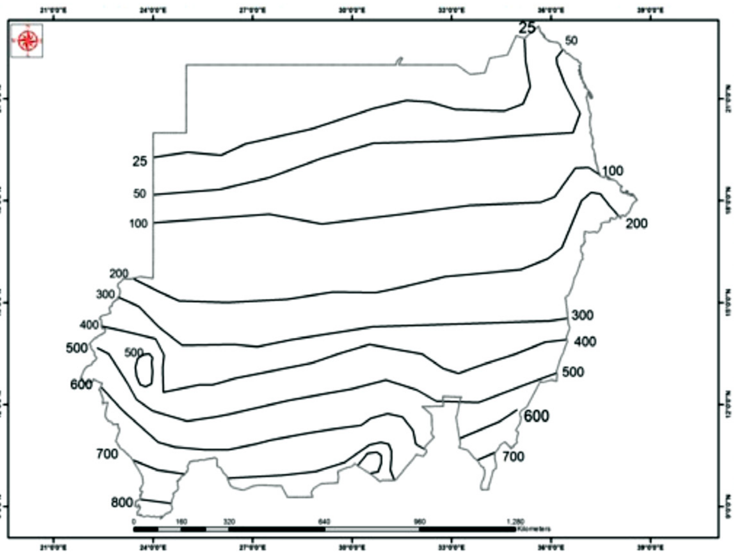


Figure (1): Maximum and minimum temperature degree over Dongola town (1981-2010)

Source: http://www.sudapedia.sd/ar/content/136

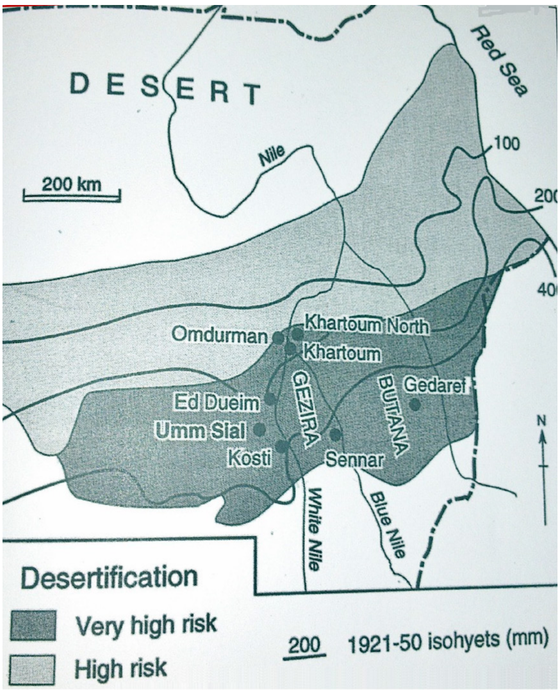


Map (3): Sudan long term average of GHI, period 1994-2015 (KWh/m2 daily totals and yearly totals). Source: After Global Horizontal Irradiation, Sudan, Solar Resource Map, World Bank Group



Map (4): Annual rainfall over the Sudan

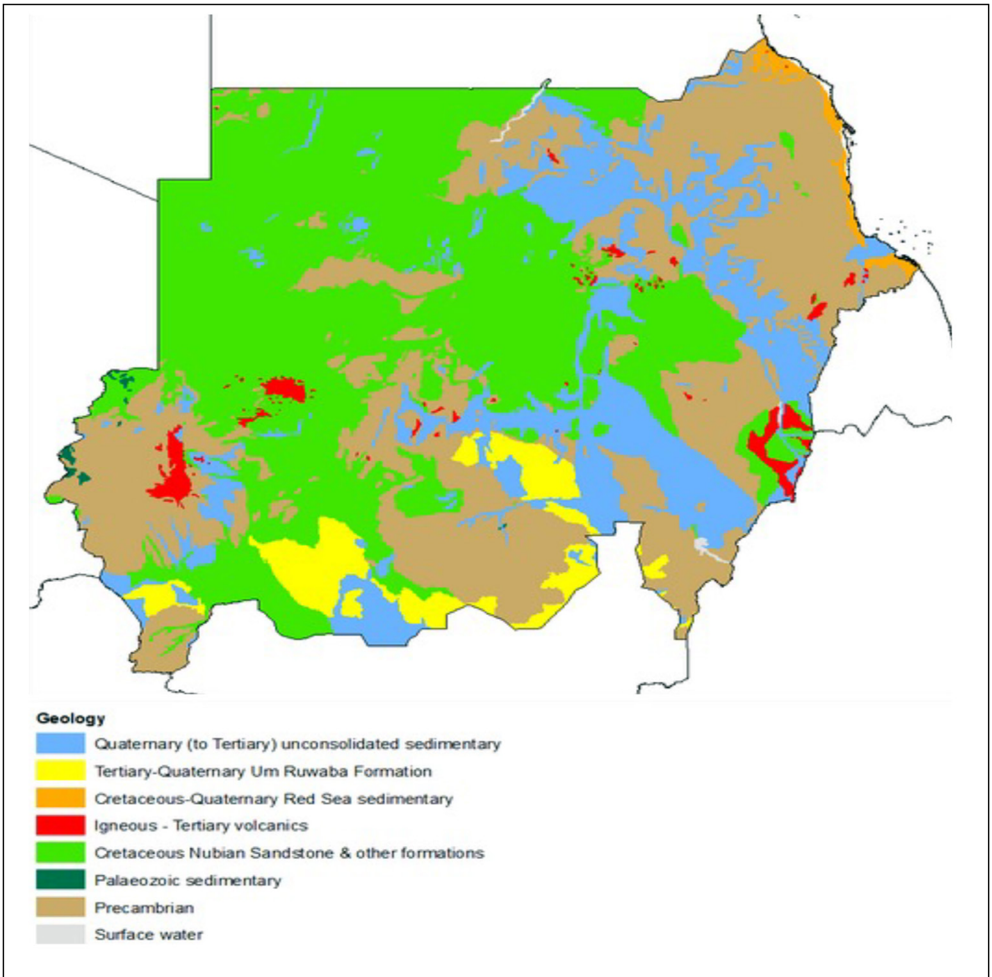
Source: El-Tom and Abdallah,2010



Map (5): Desertification Map of Sudan

Source: Alredaisy and Davies, 2001.

Basement complex rocks are the most extensive type of rocks in Sudan (49%), with the exception of superficial deposits (3%))Whiteman1971, GRAS 2006) (Map 6). Basement Complex was differentiated into Gneiss Group and Schist Group, while granulite and the amphibolite facies were recognized in the Gneiss Group. Reference to map (6) the northern half of the Sudan is characterized by vast expanses of aeolian sands which obscure the bed rock. The sands are prevailing in the northwestern parts of the state and west of the Nile. Nubian sandstone series consist of badly sorted and coarse to medium sandstone with brown or creamy color with the presence of quartz pebbles and mud flakes and lenses of clays.



Map (6): Geology of Sudan (Source: GRAS 2006)

Wadi Halfa's map (30-36 E, 20-Epyptian borders) shows a depression area of rocky and sandy area with an elevation of 300 m with some big mountains to the west of the Nile (GRAS ,1995). Between the Nile and the railway, a desert of rugged hills is found with some sandy narrow wadis which reach to an elevation of 1240m at Jebel Kurkur in the middle. The railway follows a wide sandy basin that becomes narrow in the south (10-15 km), however it widens northwards to 200 km along the border and filled up with deposits. To the east of the sandy depression a narrow hilly desert area is found, and wide sandy wadis are found. In Dongola and Berber map (16-20 E, 30-36 N) pitches of hilly desert are found east of the Nile and north of Atbara town till Abou Hamad town which crossed by Atmour wadi. Atbara River is covered with recent fluvial deposits and sand dunes while Bayoudh desert is a rocky sandy desert composed of basement rocks with some fields of lava and cinder cone complexes, and the rest of the area is composed of sandy and rocky desert with escarpments and plateau of sedimentary rocks separated by open sandy plains and inactive dunes areas. The majority of sand dunes lying in topographic depressions of eastern desert, including some parts of northwest parts of the study area, mostly composed of quartz and sandstone and barren along the majority of southern part of the study areas (El Baz 1998).

Basement Complex rocks in northern Sudan are exposed along the course of the Nile and around Jebel Uweinat. In the central part of the State basement complex and rocks are mostly in the form of N-S elongated exposure while Aaeolian deposits consistof dune, inter-dune and sand sheets (Abuzeid, et al., 2017). The basement rocks along the Nile is made up of quartzo-feldspathic biotite and hornblende gneisses, quartzites, micaschists, marbles and amphibolite lenses; basic volcanic rocks, minor gabbroic bodies followed by granitic batholiths and dikes. The Cambrian rocks in the Sudan are represented by the Nawa Formation and the Amaki Series (Ahmad et al., 1984).The Amaki Series (Am) is represented by small outcrops of sandstones and conglomerates with some limestones andcherts, observed between Abu Hamad and Shereik in the study area. The sediments of Umm Ras Beds range in thickness from 150 to 250 m. The rocks of the Hudi Chert Formation are fossiliferous cherts, found inbetween Shendi and Atbara, usually not far from the Nileor its tributary wadis. The chert occurs up to about 30 cm diameters and is characteristically yellowish brown (Ahmad 1984 et al.,).

Silurian sandstones were recorded in northwest of the study area. Some cross-bedded, fine to coarse- grained friable sandstones were also noted west of the river Nile, between latitudes 20° and 21° N, and in the northwest corner of the Sudan. In the area south and southeast of Jebel Kisser, the Basement Complex rocks are overlain by a relatively thin sequence of Silurian sandstones. Similar outcrops were also found west of the Nile (Ahmad et al., 1984) (See Figure 1).

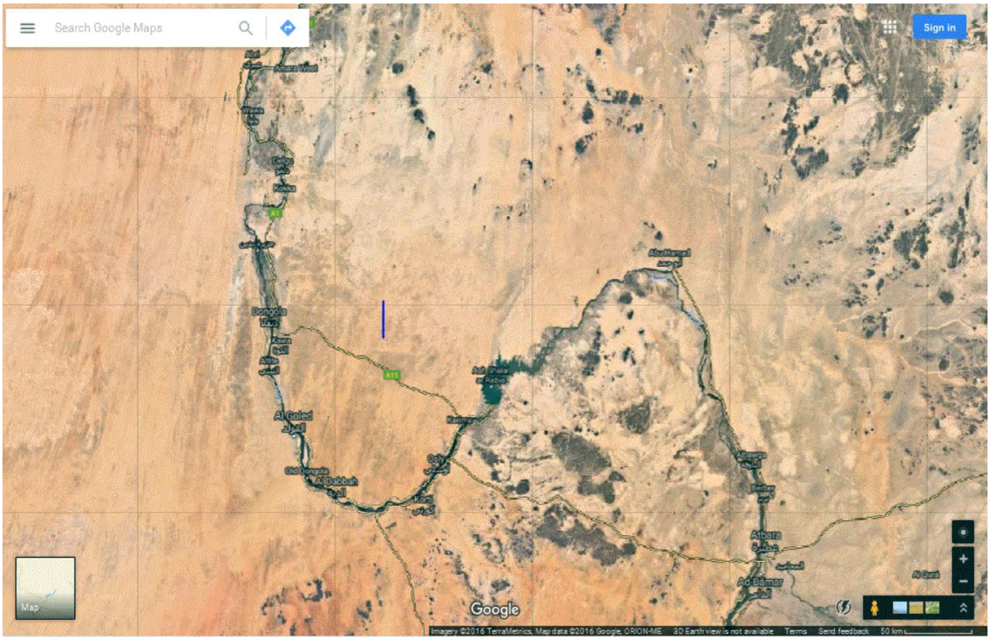


Fig.2: Geological landscape of Northern State.

Source: Google Maps, 2018

Some outcrops of Devonian to Carboniferous age, made up of sandstones, siltstones and shales, containing mainly continental plant fossils were noted west of Wadi Haifa. At Karuk Murr, Lower Carboniferous formations directly overly the basement rocks. The formation is 80 to 90 m thick (Ahmad et al., 1984).Three formations of Carboniferous sediments were recognized in the northwest corner of Sudan including Karkur Murr sandstones formed of conglomerates, siltstones and micaceous sandstones, the Wadi Waddan shales, is made up of about 300 m thick strata of fine sandstones, siltstones and variegated shales, and Cima sandstones, i.e., massive quartzitic sandstones, nearly 400 m thick (Ahmad et al., 1984). The dunes in the central part of the State are typically developed in unimodal wind regime (NNE wind prevailing in the Northern Sudan, and located at the right bank of the river Nile (Abuzeid, et al., 2017).

Nubian Sandstone outcrops are mainly confined to the northern part of the country, overlies the Basement Complex rocks over most of its outcrop areas. A rare 15 cm thick lignite horizon was reported near Dongola, gypsum near Shendi. Calcareous andferruginous horizons are also common (Ahmad 1984 et al,).Small outcrops of acidic and intermediate volcanic of mainly rhyolites and trachytes (Av) were noted between Red Sea Hills and River Nile (Figure1).

The derivational approach on climatic and geological data on the Northern State could give the following results:

1. The northern state is a typical hyper - arid environment where four solar irradiation regions could be distinguished from map 3: -
    - Region 1 receives (6.8; 2483 GHI, KWh/m^2 daily totals and yearly totals), and covers small area in the northeast part of the study area (hyper aridity)
    - Region 2: receives (6.6; 2410 GHI, KWh/m^2 daily totals and yearly totals), and found to the east of region 1 in three patches covering a larger area relative to region1 (higher aridity)
    - Region 3: receives (6.4; 2337 GHI (KWh/m^2 daily totals and yearly totals), and stretching diagonally from northeast to southwest with a huge area relative to former two regions and region 4 (high aridity)
    - Region 4: receives (6.2; 2264GHI) and stretching south of region 3 in small area relative to region 3.
2. These four solar regions are receiving the highest levels of solar irradiation over the Sudan similar to North Darfur State and some parts of Red Sea State (Map3). The range of GHI is 6.2 to 6.8 (KWh/m^2) daily totals where times of highest received irradiation during the day are strongest between

10 am and 4 pm. These higher solar irradiation rates over the study area could be related to lying within the desert climatic region with high temperature during summer and spring months, lower humidity due to lower precipitation and high rates of evaporation, i.e., hyper – arid environment (Maps 2, 4 and 5, and Fig.1). They are more determined by distance from the equator, latitude, and altitude where more UV rays reach the ground at higher elevations.

3. The geology of the study area gives the following results (map 6):

o Basement Complex rocks in some parts of the study area is made up of quartzo-feldspathic biotite and hornblende gneisses, quartzite, micaschists, marbles and amphibolite lenses; basic volcanic rocks, minor gabbroic bodies followed by granitic batholiths and dikes.

- Basement rocks in other parts of the State are overlain by a relatively thin sequence of Silurian sandstones.
- Small outcrops of acidic and intermediate volcanic rocks, mainly rhyolites and trachytes (Av) were noted.
- Nubian sandstone series consist of badly sorted and coarse to medium sandstone with brown or creamy color with the presence of quartz pebbles and mud flakes and lenses of clays.
- Nubian sandstone in the central part of the State is striking out as dissected ridges east of the Nile and Elkhowei dune filed and alluvial deposits (Abuzeid et al., 2017).
- Some cross-bedded, fine to coarse-grained friable sandstones was also noted.
- There are some sandy deserts composed of basement rocks with some fields of lava and cinder cone complexes, while sand dunes lying in topographic depressions mostly composed of quartz and sandstone.
- Small outcrops of sandstones and conglomerates with some limestones and cherts, and some outcrops made up of sandstones, siltstones and shales were noted.

- Formations of Carboniferous sediments were made up of conglomerates, siltstones and micaceous sandstones, and shales are made up of fine sandstones, siltstones and variegated shales.
- Massive quartzite sandstones (Cima sandstone) are nearly 400 m thick.
- Vast expanses of aaeolian sands obscure the bed rock and Nubian Sandstone outcrops overlie the Basement Complex rocks.
- Depressions of rocky and sandy areas, desert and pitches of rugged hills, narrow hilly desert areas, wide and narrow sandy wadis were found,
- Sandy and rocky desert with escarpments and plateau of sedimentary rocks separated by open sandy plains and inactive dunes areas are found.
- In the central part of the State the sand sheets are flat or gently undulating bodies of sand up to several meters thick are extending many or even hundred kilometers horizontally(Abuzied,etal.,2017).

4. These results are indicatively confirming that igneous rocks are intrusive; extrusive; ultra mafic; mafic; medium; and acidic, while sedimentary rocks are dominantly terrigenous (including sand dunes and sand sheets), chemical, and organic ones, and metamorphic rocks are mainly gneiss and schist groups (table 2).
5. Granite rocks dominate where their chemical composition by weight is 72.04% of silica (SiO_2). They all together, except those sedimentary rocks of chemical and organic origin, affiliated to silicate minerals (table 2), particularly quartz.
6. The sand origin is decomposed granite which inevitably is silica (SiO_2).

Table (2):
Rock types, mineral content, surface color, and absorb factor in the study area

Rock Group	Rock types	Mineral content	Surface Color	Absorb * Factor
Igneous	biotite, , batholiths and dikes, minor gabbroic bodies, rhyolites, trachytes	amphibolite lenses, quartzo-feldspathic, granitic, mica	Dark blue to black	0.90 - 0.80
	basic volcanic rocks		Light color	
Metamorphic	Gneiss Group Schist Group, granulite and the amphibolite facies were recognized in the Gneiss Group, hornblende gneisses, marbles, Greenschists	Granulite and the amphibolite facies, quartzites, micaschists	Grey to dark grey	0.50 - 0.40
	,marbles		Light color	
Sedimentary	aeolian sands, sand dunes, quartz, conglomerates, , siltstone, shales, micaceous sandstones, quarzitic sandstones	quartz	Green, red and brown	0.70 - 0.50
	limestones, cherts, pebbles and		Light color	
	mud flakes, lenses of clays		Dark color	

Derived from information on study area's geology, * Fraction of Incident Radiation Absorbed (Reference table 1).

7. **Rock types and absorption of solar irradiation:** Physical and chemical characteristics of rock types determine their colors and consequently fraction of incident radiation absorbed as shown by table (2) with reference to table (1). This gives that the igneous rocks absorb up to 90% of irradiation (average is 85%), sedimentary rocks absorb up to 70% (average is 60%), while metamorphic rocks absorb up to 50% (average is 45%). The general average for the three major rock groups is 63.33%. This means that rock types of the study area are inherently acquiring higher ability of absorption of solar irradiation. Granite is a natural source of radiation, where some granite has been reported to have higher radioactivity. Some granites contain around 10 to 20 parts per million (ppm) of uranium. By contrast, more mafic rocks, such as gabbro and diorite, have 1 to 5 ppm uranium, while limestones and sedimentary rocks usually have equally low amounts.

8. The population of the study area are mainly concentrated in solar irradiation regions of 3 ‘’with high aridity’’, and region 4 (Map 3). They receive rates of solar irradiation at 6.4 and 6.2 GHI respectively, but adversely affected by the nearby solar irradiation region 2 ‘’with higher aridity’’ (Map 3). These altogether confirm that the population of the study area is highly vulnerable to higher levels of solar irradiation. This is more adverse by spending long hours under direct sun radiation as the majority is farmers.

Discussion:

The study area lies within the hyper arid environment and also within the belts receiving highest rates of solar irradiation over the Sudan. This conforms to higher values of estimation of global solar radiation and its correlation with bright sunshine duration over Sudan (Alivi, 1995). These erratic conditions are being more effective by climatic changes where there was an increase in the earth surface temperature during the 20th century by 0.740.18 ± C° and is expected to increase more by 1.4 C^0 to 5.8 C^0 up to the year 2100 which gave the opportunity to severe wind erosion and dune advancement by rates at 6m/year for large dunes and 23 m/year for small ones between 1961-2000 (Abuzeid 2017). These altogether provided greater opportunity for exposure to UV, X-rays and gamma rays, that was catalyzed by the fact that, the 98.4% of the Northern State area is covered by bare rocks and soils or/

and other unconsolidated materials (FAO, 2012) and the bulk of rocks composing the study area are originally composed of silicate minerals where their solar absorb factors and reflectance indices (SRI) were confirmed to be high.

Several studies have pointed out to the geographical associations between geochemical variables and the occurrence of certain human diseases (Armstrong1971), where a number of environmentally related endemic diseases arise from, for example, the geochemistry of loess and its groundwater's (Edward, 2001). The results of our study were supported by these facts and even further supported by that in the major urban areas of the United States the risk of fatal breast cancer was inversely proportional to intensity of local sunlight (Frank et al., 1990). It is even more certain that there is persuasive evidence that each of the three main types of skin cancer, basal cell carcinoma (BCC), squamous cell carcinoma (SCC) and melanoma, is caused by sun exposure (Bruce et al. 2001). There is a visible difference in the pattern of cancer in the Malabar region and the southern parts of Kerala, which could be related to the many factors among which is topography and ecological conditions (Sudhakaran, 2016). This is more elaborated by that a relationship exists between cancer types and elevation where 54.2 % of all cancer types occurred at 0–250 m, 20.7% at 251–500 m, 11.1% at 501–750 m, 6.6% at 751–1,000 m, and 7.4% at an elevation of more than 1,000 m (Tahsin et al., 2009). Furthermore, examining the percentage of cancer cases by land cover classes showed that 47.8% corresponded to agriculture, 33.8% to forestry, and 18.3% to residential areas. This could mean that, since the population of the study area is agriculturalists and settled along the fertile land on both banks of the river Nile, such results could correspond to incidence of cancer among them. It is also evident by geographic observation that the increased mortality of some cancers at higher latitudes has led to a hypothesis that vitamin D produced after exposure to solar radiation has anti-carcinogenic effects; and increased exposure to solar radiation reduces the risk of cancers of the digestive organs (Mizoue, 2004). Ultra Violet rays, X-rays and gamma rays which are produced by radon gas, are quite risky because they can get into the soil and rock, the air, and into underground water and surface water which can further support our suggestion, here. This even more supported by what has been stated by Lancet (1996) that solar ultraviolet radiation decreases with increasing latitude (towards Sahara Desert for example), and the incidence of squamous-cell carcinoma of the eye decreased by 29% per unit reduction in ultraviolet exposure. This even further supported by that the pattern of increased breast cancer incidence in regions of low solar radiation in the USSR is consistent with the geographical pattern seen for breast cancer mortality in the US and worldwide (Edward, et al, no date). The annual exposure to carcinogenic sunlight in Norway showed no increasing trend during the same period, and thus, ozone depletion is not a cause of the increasing trend of the incidence rates of skin cancers (Moan et al.1992). Since the rocks of the study area are liable for Radon gas production it has been confirmed that this Gas is the number two cause of lung cancer in the United States behind smoking. In addition, since the study area also experiences dust storms during summer and winter seasons, it has been indicated that radon progeny attaches to dust and other particles and can be breathed into the lungs, while its breakdown in the air gives off radiation that can damage the DNA inside the body's cells. The content of silica in the study area's rocks is hazardous as such as that to the workers in Turkish construction industry and quarries, who are exposed to silica mineral dust from natural stones which could lead to lung cancer (Dal et al., 2012).

Conclusions:

1. A dual influence of the arid environment and the type of mineral content of rocks on cancer morbidity in the northern state of Sudan is stated.

2. The results of this research are applicable to similar environments providing that applied research is done.

3. The ecological approach for understanding the etiology of cancer in Sudan is critical.

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2

Expectancy of Shifting Malaria Endemicity from Hypoendemic to Mesoendemic with Agricultural Expansion Into Deserts of Northern Sudan

2

Expectancy of Shifting Malaria Endemicity from Hypoendemic to Mesoendemic with Agricultural Expansion Into Deserts of Northern Sudan

Malaria is a serious tropical disease disrupting the social and economic life of many African communities in both rural and urban areas. It is estimated that malaria threatens the lives of 40% of the world's population and is a public health problem in more than 90 countries to varying degrees (World Health Organization, 2012, 2015); a serious parasitic disease worldwide (Yongze et al.2016) and one of the largest obstacles to socioeconomic advancement (WHO, 2016). In the AFRO area the population at risk grew from 0·06–0·65 billion during the 20th century, more than 80% of whom remain in areas of hyperendemic and holoendemic malaria (Carter et al., 2002).

Plasmodium is the agent of the disease and of its various forms, the most serious is *Plasmodium falciparum* which on average proves fatal in 10% of cases caused by it (Meade et al., 1988). The vector by which the disease is transmitted is the *anopheles* mosquito. As the breeding sites for the mosquito are stagnant water, malaria was originally associated with rural rather than urban areas. Large areas of the world have climatic conditions conducive to the breeding of malarial mosquitoes, including not only tropical lands but also many areas with warm temperatures and Mediterranean-type–type climates (Prothero, 2001). The best conditions for the *anopheles* are said to lie in temperatures between 25^0 and 35^0 C, with relative humidity at 60%and a rainy season of at least three months. Temperatures below 16^0 C and above 37^0 C are not so conducive to their survival (Akhtar et al., 1977). The degree of efficiency of malaria vectors to transmit malaria from one human to another is an important factor defining the distribution of malaria in Africa. The distribution of malaria is most influenced by its mosquito vector, which is sensitive to extrinsic environmental factors such as rainfall and temperature. Temperature also affects the development rate of the malaria parasite in the mosquito (Leahman et al., 2010). Because environmental variables are mostly correlated in space, significant spatial association is expected in the spatial patterns of malaria (Osei et al., 2015).

No recent global maps of malaria endemicity have been developed since those of Lysenko in 1968, despite significant advances in the collection of empirical data, global environmental information from satellites, and the statistical techniques that can be used to integrate them (Simon et al.,2004). Endemicity of malaria as used by Lysenko was defined by the parasite rate in the 2–10-year age cohort (Hypoendemic<0·1; Mesoendemic 0·11–0·5; hyperendemic 0·51–0·75), except the holoendemic class (>0·75) where the parasite rate refers to the 1-year age group (Metselaar et al., 1959).

A change in the distribution of malaria is foreseeable due to the potential consequences of anthropogenic climate change. An increase in the Earth's temperature and precipitation can create conditions more conducive for the breeding of the malarial vectors. Some studies suggest that climate change can alter the distribution of vector-borne diseases, including malaria, causing regions that are currently free of such diseases to be affected. Thus, climate change could extend the distribution of the *Anopheles* vector, which is found worldwide except in very cold regions, such as Antarctica. "The considerable change in land-use practices resulting from increasing irrigation in recent decades raises important questions on concomitant change in malaria dynamics and its coupling to climate forcing. Irrigation can lead to more endemic conditions for malaria, creating the potential for unexpectedly large epidemics in response to excess rainfall" (Baeza et al., 2011).

Demographic factors and despite human activities have reduced by half the land area supporting malaria, demographic changes resulted in a 2 billion increase in the total population exposed to malaria risk (Simon, et al.,2004). Although population growth will not substantially change the regional distribution of people at malaria risk, around 400 million births will occur within the boundary of the current distribution of malaria by 2010 (Simon, et al.,2004).

"Human-made ecologic transformations such as water resource development projects have led to a history of facilitating a change in the frequency and transmission dynamics of malaria due to proximity to irrigation schemes. Whether an individual water project triggers an increase in malaria transmission depends on the contextual determinants of malaria including the epidemiologic setting, socioeconomic factors, vector management, and health-seeking behavior" (Keiser et al., 2005). The high rates of population growth in Sudan and the demand for food have increased the area under agricultural production including reclamation of arid and semi-arid lands and consequently malaria is associated with irrigation schemes.

Malaria endemicity in Sudan:

In Lysenko and Semashko's map of malaria endemicity (Figure 1) the desert of Sudan is malaria-free. Hypoendemic malaria is restricted to the river Nile and includes a very small area from the northern parts of central Sudan. Southwards from the Hypoendemic zone malaria becomes Mesoendemic in central Sudan and then hyperendemic in the former South Sudan (Lysenko et al., 1968). Malik and Khalifa (2004) indicated that South Sudan is holoendemic and that 80% of Sudan's population is living in epidemic-prone areas with unstable malaria transmission. Aal and Elshayeb (2011) produced a map (Figure 2) and table (Table) for malaria epidemiology in Sudan which agrees with Lysenko's map (Figure 1) and Malik and Khalifa (2004) while introduced urban malaria as a Mesoendemic similar to central Sudan. The whole of central Sudan, as far north as Atbara town on the main Nile, has climatic conditions conducive to the spread of malaria (Dutt et al., 1978). The dominant species of malaria-carrying mosquito is *Anopheles arabiensis*and the main parasite involved is *Plasmodium falciparum*, the main cause of malignant tertian malaria (Hamad, 2002). In 2010 the majority of the geographical area of the Sudan had a risk of <1% PFPR 2-10. And about 80% of Sudan's population was in the areas in the desert, urban centers, or where risk was <1% PfPR 2 (Abdisalan et al., 2012).

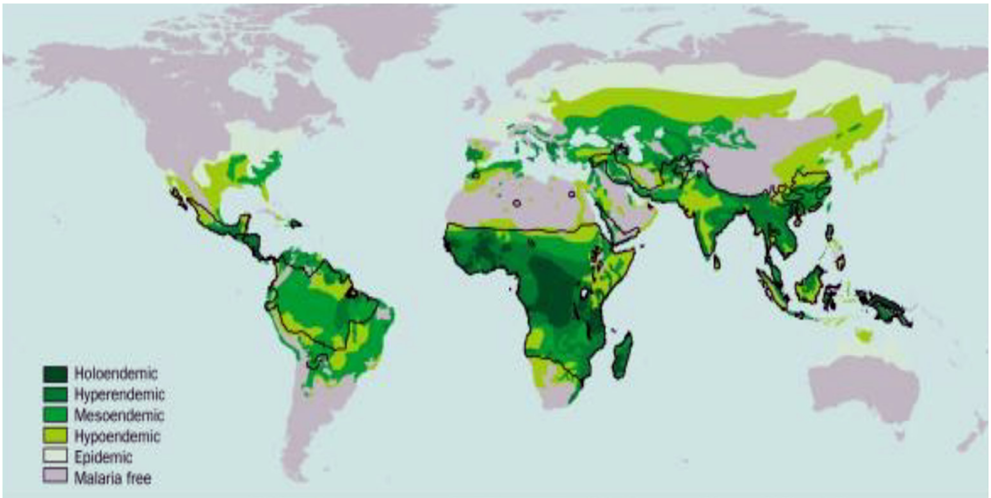

Fig.1. Global map of malaria endemicity

Source: Lysenko A J. and Semashko I N. 1968.

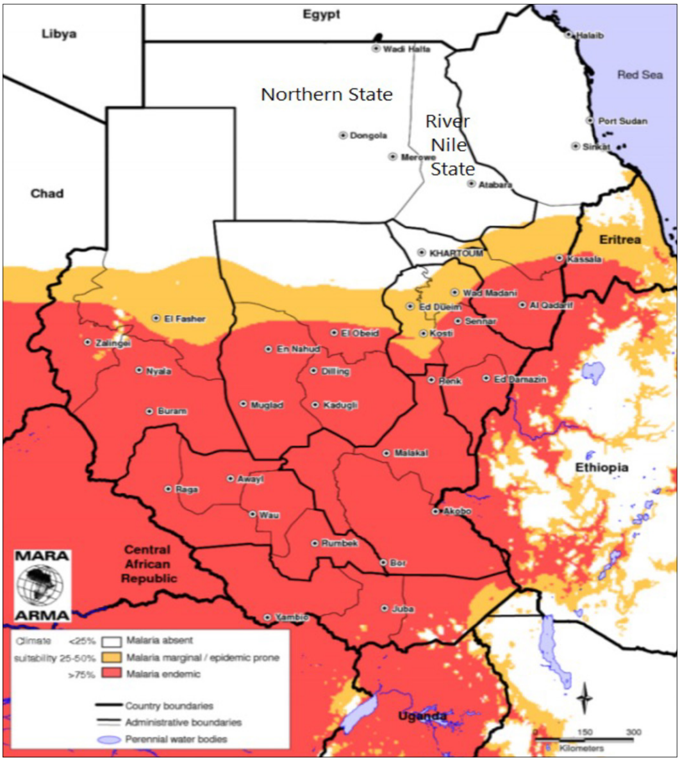

Figure2. Distribution of malaria in Sudan

Source: After Aal A.R. and Elshayeb A.A. 2011.

Table1. Malaria epidemiology in Sudan

strata	classification	Annual parasite incidence	Number of populations	Malaria intensity
Desert fringe	Hypoendemic	3.8	1,000,000	Unstable
Poor savannah	Mesoendemic	4.8	20,000,000	Unstable
Rich wet savannah	Hyperendemic	1.5	4,000,000	stable
Urban malaria	Mesoendemic	0.3	5,000,000	Unstable

Source: Aal A.R. and Elshayeb A.A.2011.

In 1995 malaria topped the list of disease admissions to Sudan's hospitals and it was the major disease killing children less than 4 years of age, accounting for more than one-third of all hospital deaths for this age group (Ministry of Health, 1995). During the period 1997-2007 (Figure 3) the Northern State came second to the Blue Nile State in malaria cases although they differ significantly in climatic conditions. The River Nile State (Nahr Elnil) is almost similar to Kassala and Khartoum States which lay into somehow rainy zone in central Sudan. During the period 2007-2017 (Federal Ministry of Health, 2017) the Northern and River Nile States still kept a higher record in malaria incidence (Figure 4) although the annual increase of the population in the Northern was 2.1% and came last in ordering of Sudan's States by population number (Ministry of Finance and Economic Planning, 2008). In the view of this study, high records in malaria incidence in the two States are not thoroughly due to increase of population or good reporting to hospitals, but to new agricultural expansion and building of dams in both States.

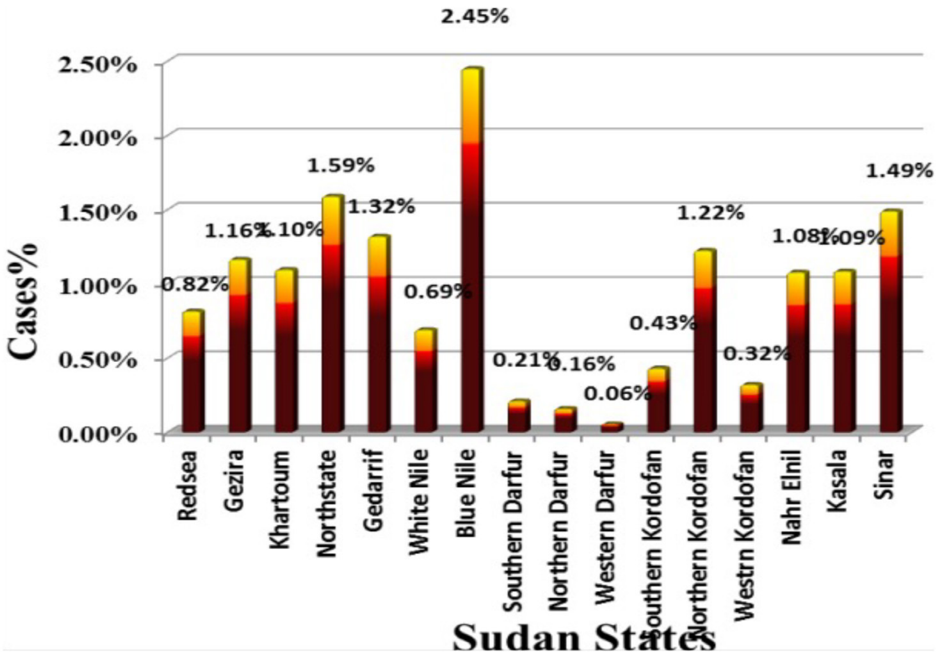

Figure3: malaria cases among Sudan States 1997-2007

Source: Aal A.R. and Elshayeb A.A.2011.

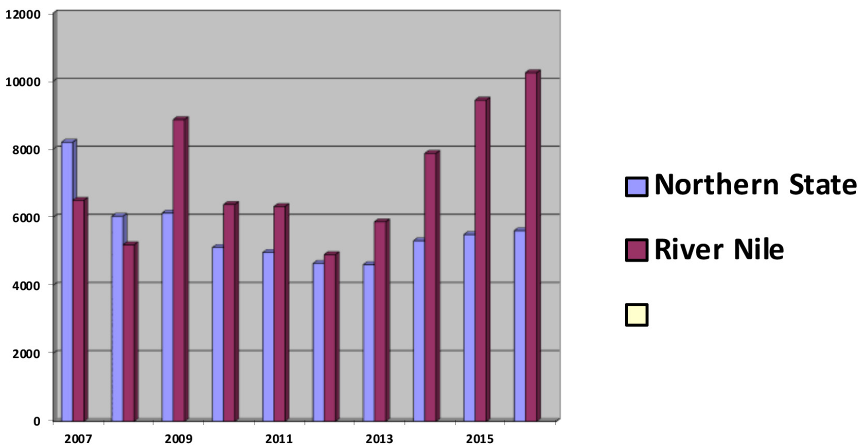

Figure 4: Malaria Inpatient in Northern and River Nile States: 2007-2017

Source: Federal Ministry of Health, 2017

The Northern state with an area of approximately 348,765 km^2, lies between latitudes16°N and 22°N; and longitudes 20°E and 32°E provides a huge area for mosquitoes to niche. This is enhanced by the river Nile which bisected the two States. Both banks of the river Nile are occupied by a population who were estimated at 699,065 inhabitants in the Northern State, 80% of them live in rural areas; and some others are nomads, giving a total density of 2 persons /km^2 (Ministry of Finance and Economic Planning, 2008). The River Nile State lies between latitudes 16^0 N and 22^0 N and longitudes 32^0 E and 35^0 E. The two States lie within the desert climatic region of Sudan). The Minimum average temperature is witnessed during January which might be below 10 C ^{0}. The maximum average temperature exceeds 40 Celsius degrees during the summer months of April, May, June, July, and August, due to absence of clouds and the prevalence of dry northeast winds. Therefore, they receive the highest levels of solar irradiation over the Sudan. Annual rainfall is infrequent and ranges between 200 mm to 25 mm northwards which means very low humidity levels and a poor sparse desert vegetative cover. The two states are also under higher onsets of desertification and sand encroachment which excavate the desert climatic conditions. These general climatic conditions might seem to be hostile for malaria mosquitoes; however, factors such as that *A. Arabiensis* exhibits considerable ecological and behavioral plasticity allowing it to survive in harsh conditions of arid regions, changing climatic conditions and recent expansion of agricultural schemes and building of dams.

Vast expanses of aaeolian sands are prevailing in the north-western parts of the Northern state and west of the Nile. There are small outcrops of sandstones and conglomerates with some limestone and cherts. Some cross-bedded of sandstones were also noted west of the river Nile between latitudes 20° and 21° N, and in the northwest corner of the Sudan. Nubian sandstone outcrops overlie the basement complex rocks (Ahmad et al., 1984). These basement complex rocks are exposed along the course of the Nile and in the central part of the State which are mostly in the form of N-S elongated exposure while Aaeolian deposits consist of dune, inter-dune, and sand sheets (Abuzeid, et al., 2017). This harsh geologic environment is expected to be participatory influencing malaria incidence like climate; however, the intervening factors have to be considered.

Data sources were Dams Implementation Unit, Sudan (diu.gov.sd), Federal Ministry of Agriculture, Federal Ministry of Health, and National Centre for Health Information (NCHI.Gov. Sd.), Tekno Consultancy Company, relevant books on geology and climate of Sudan, and relevant scientific research on Google Scholar. The comparative and analytical approaches were applied to justify the research problem. The east-west line extending along the southern parts of the desert and separating Hypoendemic from Mesoendemic malaria zone was taken as the datum for the statement of this study. The relevant research results at national, regional, and international levels were used to rationalize this research statement.

The proposed model (Figure 5) consists of six integral parts, without priority of order, to achieve the model's proposed purposes and purposively work to try to keeparid Sudan, as exemplified by Northern and River Nile States, as a Hypoendemic area rather than to become a Mesoendemic area of malaria endemicity, and also to contribute into future complete eradication of malaria.

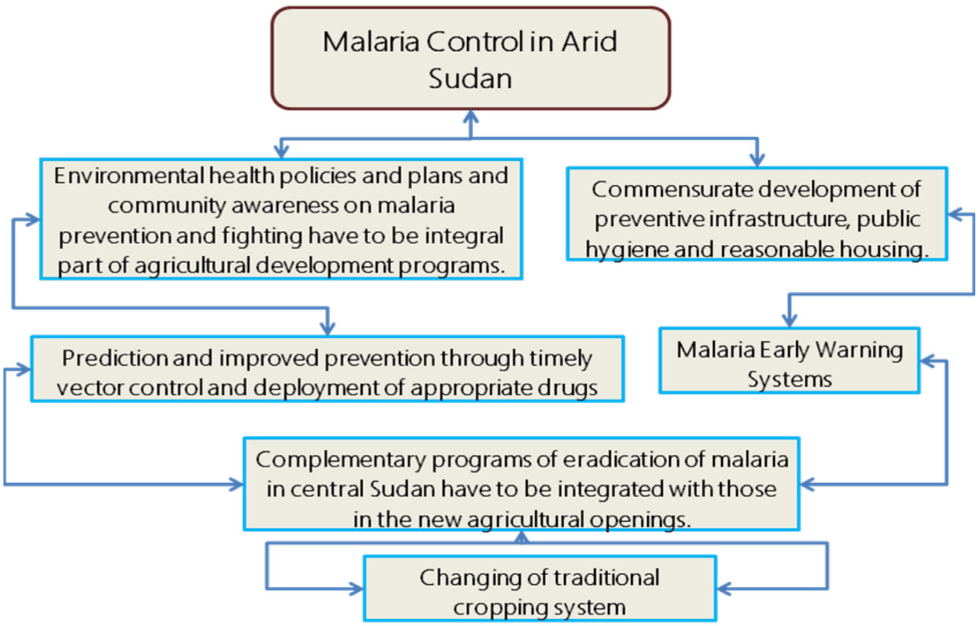

Figure 5: A Proposed model for control of malaria in arid Sudan

Agricultural expansion in the Northern and River Nile States:

The total agricultural area in the Northern State was estimated as 14 million feddans where 49% is arable land (Ministry of Finance, Northern State, 2003:25). Types of soils in the Northern State according to Musned (2000) include Desert; Riverain; lands of recent flood plain and flood lands (covered by Nile water annually); mid-terrace lands (irrigated by water pumps and relatively remote from the Nile); high-terrace lands (remote from the Nile and never reached by flood water and they were part of flood plain lands but erosion factors have changed their contour); and soils of old Nile channels and their tributaries such as Wadi Mugadem and Wadi Ga'ab which are characterized by fertile loamy soil. Many agricultural systems were applied (Table 2) with a dominance of private schemes extending along the river Nile, while many other schemes were irrigated by artesian water (Table 2).

Table (2): Agricultural systems in the Northern State

Agricultural systems	number	(Cultivated area (Feddans
Co-operative societies	159	116720
Agricultural companies	55	135900
Nile private agricultural schemes	7647	93985
Artesian private agricultural schemes	15,131	120486
Total	22,992	467091

Source: Northern State, Ministry of Agriculture, Dongola, 2008

The total area suitable for agriculture utilization in the Northern State was 352,419 feddans. 49.2% of that area was utilized by 182 governmental and privately owned agricultural schemes while 50.8% remained uncultivated (Northern State, Ministry of Agriculture and Animal Resources and Irrigation, 2008). Over the remaining and newly introduced lands recent agricultural expansion took place (Table 3) by National private sector and Arab investment (Figure 6). Some of these schemes extend along the river Nile (Table 3) with a total area of 1,116,000 feddans beside some proposed ones with an estimated total area of 840,000 feddans into adjacent desert's fertile lands to depend on artesian water for irrigation (Table 4 and Figure 6). So, the estimated grand total of all agricultural expansion is 1,956,000 feddans and is expected to reach more than 2,000,000 feddans by the largest center-pivot irrigated alfalfa farms across 87,200 hectares in Wad Hamid area (US-Sudan Business Council, 2018).

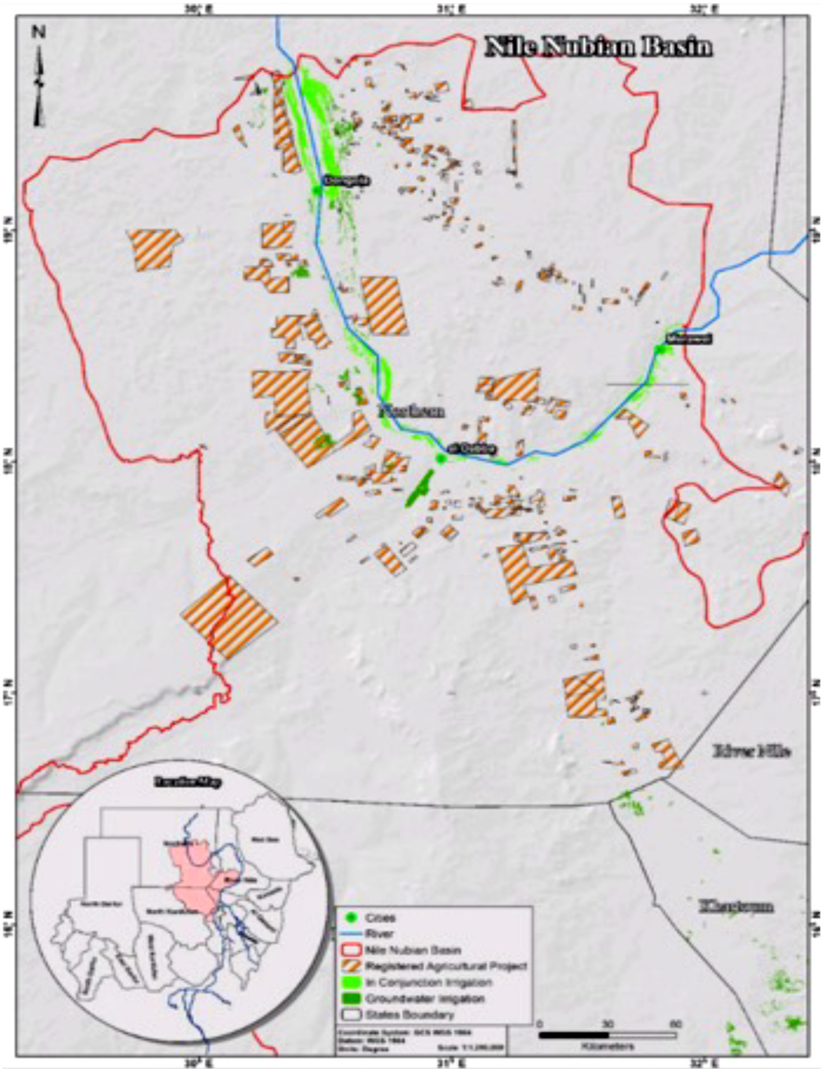

Figure 6: New agricultural schemes in Northern State

Source: Tekno Consultancy Company, 2019

Table3:
New agricultural extensions in Northern and River Nile states

Name	Location	Area (Fadden)	Irrigation
Goleid West	South of the Dongola area West of the River Nile	50,000	Nile water or artesian water or drip, axial, flash irrigation
Argein – Gamei	Gami Plain west of Halfa town on the western bank of River Nile, lies within the Nubian Basin for complementary irrigation	200,000	Direct pumping from the river Nile
khuwei for Agricultural Production	South of Sulaim basin – Dongola locality	200,000	Nile water or artesian wells
khuwei for Animal Production	khuwei Wadi – Dongola locality	250,000	Flood irrigation and surface wells
Kuka plain	Wadi Halfa locality, west of the Nile	56,000	Nile water
Alfida	Abu Hamad locality, River Nile state	30,000	Nile water
Gihad	Shendi, River Nile state	4,000	Nile water
Wadi el Sheikh for mixed agriculture	Abu Hamad locality, River Nile state	13,000	Nile water
Wadi Naga3a	West of the Nile, near Matama town	100,000	Nile water
Hamdab el Gadida	Meroei area	35,000	Nile water
Amri el Gadida	Meroe area	67,000	Nile water
Manaseir el Gadida	Meroei area	60,000	Nile water
Kehaila east	Meroei area	45,000	Nile water
	Total Area		1,116,000

Source: http://www.diu.gov.sd

Meroe dam was constructed by 346 km far north of the capital Khartoum and by 330 km of the northern borders of Sudan. Huge reservoir of water was created behind the dam extending for 176 km from the fourth cataract up to south Abu Hamad area in a desert area where new agricultural schemes and villages have developed (Dams Implementation Unit, 2019). In addition to Meroe Dam, some other Dams including Kagbar north of Dongola town and Dal south of Halfa town were proposed to be built by Dam Implementation Unit, Sudan. These Dams will irrigate the proposed agricultural extensions in the Northern State (Table 4).

Table (4): Proposed Agricultural Extensions for Artesian Irrigation in Northern and River Nile States

Name of a scheme	Area (Feddans)	Name of a scheme	Area (Feddans)
Khwei and Silaim Basin	320,000	Naga3 Wadi	200,000
West Dongola plains (Akaadm Ga3ab)	15,000	Mkabrab Wadi	85,000
Bakri and Rumi plain	15,000	Hawad Wadi	50,000
Latti basin	10,000	Lower Atbara River	40,000
Afad and Argi basin	10,000	Wadi Sial plains- West of the River Nile	5,000
Wadi Magadem	50,000	Khelaiwa – Barber area	4,000
Total	840,000		

Source: Niema Abdelkhali Mustafa. 2015. Climate change, enhancement of African environmental coping systems, Omla Printing Press, Khartoum, p. 24.

These schemes and Meroe Dam are served by roads network (table 5) which are linked by many bridges including Friendship Bridge linking Merow and Karima (432m), Dongola - Suleim (693m), Damar – Umeltuer - Akad (858m), Shendi - Metama (660m), Daba - Argi (466m), and Kasinger – Meroe Dam railway. In addition, Merowe International Airport, Merowe Hospital, Merowe Technical College were built to serve the population. These roads are expected to facilitate flow of production and people who might be carriers and hosts of malaria parasite (Dams Implementation Unit, 2019).

A. Arabiensis is opportunistic feeder and efficient vector of Plasmodium falciparum in Africa and may invade areas outside its normal range, including areas separated by expanses of barren desert, and the models used reveal large areas of future habitat connectivity that may facilitate the re-invasion of *A. Arabiensis* from Sudan into Upper Egypt (Fuller et al., 2012). Malaria is currently a serious health problem in Sudan and one which appears to be getting worse since it is threatening Sudan's desert land through vast agricultural expansion and building of new dams. These recent expansions, as exemplified by Northern and River States, could hold suggestions for spatial shifting of malaria endemicity from Hypoendemic to Mesoendemic in both the States to become similar to central Sudan. Relevant research results could rationalize for that particularly where "the association of malaria with irrigation in arid lands has been known in ancient and recent history" (Farid,1977) and that increased numbers of vectors following irrigation can lead to increased malaria in desert fringes (Ijumba, 2001).

Table (5): Road network serving the new agricultural schemes in Northern and River Nile States

Name of Agricultural Scheme	Location Description	Length Km.
Goleid West	Close to Dongola-Khartoum-Highway and Dongola Airport	-
Argein – Gamei	Close to asphalt roads and railways and air transport	-
khuwei for agricultural production	Close to Dongola-Khartoum-Highway and Dongola Airport	-
khuwei Scheme for Animal Production	Close to Dongola-Khartoum-Highway and Dongola Airport	-
Kuka plain	-	-
Alfida	Abu Hamad-Atbara Highway, Challenge Road to Port Sudan and railways, all roads connecting the capital Khartoum with all states of Sudan	-
Gihad	Asphalt roads and railways	-

Wadi el Sheikh for mixed agriculture	Abu Hamad-Atbara – Khartoum Highway, then Challenge Road Atbara–Haya-Port Sudan and railways, all roads connecting the capital Khartoum with all states of Sudan	-
Wadi Naga3a	Asphalt and country roads connecting River Nile state with Khartoum capital and Challenge Road connecting the state with Port Sudan	-
Merowe- Dam	Connecting Merowe town with the dam	36
Karima-Dam	Connecting Karima town with the dam	27
Karima- Nawa	Connecting the two towns	180
Shirian el Shimal	Connecting Khartoum city with many towns	254
Merowe- Multaga	Multaga is a nodal point for many roads (Shirian, etc.)	94
Merowe- Atbara	Connecting two towns	262
Karima-Sulaim-Dongola	Connecting three areas	180
Dogola-Wadi Halfa	Connecting two towns	412
Dongola - Khartoum	Connecting Capital of Sudan with all the Northern state	500

Source: Dams Implementation Unit Sudan. http://www.diu.gov.sd

The Northern and River Nile States have witnessed major environmental transitions since the last glacial maximum, 18000 years ago, from hyper arid desert to tropical grasslands, then to semi-desert and back to tropical desert today. Human activities and settlements patterns changed markedly with the rise and fall of kingdoms. These factors will have facilitated the spread of mosquito populations and then, by 1500 years ago, contributed to their reduction, or demise. *A. Arabiensis* exhibits considerable ecological and behavioral plasticity allowing it to survive in harsh conditions of arid regions. The “saqia” water wheel introduced at the medieval times brought an expansion of human population along the Nile and presumably a gradual reappearance of mosquitoes which continued with occasional setbacks to the present day. *Anophelesarabiensis* is the only anopheline to have been found between the second and fifth cataract and that it has remained limited to the south of Wadi Halfa over the last century with only intermittent forays into Egypt, where it caused at least two serious outbreaks (Malcolm et al., 2007). Isolation was almost complete except for limited dispersal downriver via the Abu Hamad reach (Malcolm et al., 2007). There was an inverse relationship between the Nile water level and *A. Arabiensis* production along the River Nile from Dongola where productive breeding in riverside pools was the main source of *A. Arabiensis* as the river receded (Dukeen and Omer, 1986).

In semi-arid Khartoum State, agricultural schemes provided 25% of mosquito breeding sites and perhaps 86% of these schemes' dwellers are infected with the malaria parasite (Khartoum State Ministry of Health, 1996). This was, as well observed in the new irrigation areas in the State's close proximity (El-Sayed et al., 2000), and particularly more noticed in Khartoum North which is almost surrounded by irrigation schemes (Davies, 1991) as accounted for the higher malaria incidence recorded in Khartoum State (Hag Ahmed, 1991). This was similarly noticed by Himeiden et al. (2011) in semi-arid eastern Sudan where a difference in pattern of malaria transmission was noticed between non-irrigated and irrigated areas. It was even more noticed in Wadi Halfa irrigated area where transmission and intensity of malaria is perennial and moderate rather than low (Himeidan et al., 2005). This demarcates seasonality in malaria transmission where Giha et al., (2000) confirmed seasonality in transmission and the epidemiology of uncomplicated *falciparum* malaria in eastern Sudan. They found that about 90% of malaria morbidity occurs during dry months and years of drought (Giha et al., 2000).

In the semi-desert habitat of western Khartoum State adult population of *A. Arabiensis* survive through the long dry season in a state of partial aestivation, characterized by limited feeding activity and a degree of arrested ovarian development (Aboud et al., 2014). This agrees with the study by Omer et al. (1970) who found that in the valley of the White Nile the species maintained itself by low-level breeding through the dry months

Relevant research in Africa and Asia provides supporting evidence for the discussion. The study by Kibert et al. (2010) in two villages in a semi-arid area of Ethiopia found that malaria prevalence was higher in an irrigated village than in a non-irrigated one. It is even higher during the dry season in the irrigated village than in the wet season compared to the non-irrigated village. Generally, irrigation schemes among the Ethiopian Rift Valley may intensify malaria by increasing the level of prevalence during the dry season (Kibert et al., 2010). In coastal savannah of Ghana, Okyereko irrigation project provided evidence that malaria risk was lower at the irrigated village compared to the non-irrigated village during the dry season and the likely reason is the low numbers of *An. Funestus* and *An. Gambiaes.s*. form (Wilson et al., 2005). In India, year- round irrigation and multiple cropping have given rise to an increase in the incidence of malaria over an 18-year period in the Mahi-kadana irrigation Project in Gujarat State, India. Further man-made disturbances such as over-irrigation and lack of drainage have also compounded the problem (Jayaraman, 1982). Thar Desert in India is currently suffering from the impact of repeated annual epidemics due to progress of canal-irrigation work where malaria prevalence rate was higher in an irrigated village compared to a truly desertic unirrigated village (Tyagi, 2001). *P. falciparum* malaria incidence cases have been found to increase significantly corresponding to dry months and seasonal monsoon time scales over Bikaner in Thar Desert (Jhajharia et al., 2013). “Therefore, the Thar Desert provides an excellent model for understanding the underlying factors responsible for the exacerbation of evolution of the epidemics” (Tyagi, 2004). In border counties in south-western China and especially in Yunnan Province which is semi-arid, malaria cis a serious health problem (Yang et al., 2017), and in Motou County malaria increases during summer and distributed in townships along Yaluzangby River in Mengba national minority (Zhuoma et al., 2012).

Micro-climatic changes are expected in Northern and River Nile States due to recent agricultural expansion and building of new dams. This has been confirmed by that, change in the distribution of malaria is foreseeable because of potential consequences of anthropogenic climate change as was evident in southern and south-eastern Asia (Hassan, et al., 2016). Since malaria is known to be sensitive to climate factors it could consequently develop for several months in most areas of Sudan (Aal and Elshayeb, 2011), including both States although they have maximum average temperature above 37^0 C and minimum average temperature below 10 C ^{0}, which are not so conductive to the malaria mosquito's survival (Akhtar et al. 1977). It also expected that introduction of animal keeping and forests plantation into these new agricultural expansions will contribute in malaria transmission and endemicity. This supported by that, agricultural settlements, as well as small-scale cattle-farming, currently represent major colonization schemes in the Amazon and correspond to important foci of malaria. Also, forests associated with agricultural development might help also in the spread of malaria in the two States since forest coverage has proved to be a significant risk factor for malaria infection in a hilly forest area of Bangladesh (Ubydul et al.,2009).

The huge water reservoir created by Merowe Dam is expected to increase malaria incidence in such arid environment of the Northern State, and is expected to be more influential by the completion of the proposed Dams. These dams could hamper river flow and water level variation; acting as reservoirs of larvae; produce year-round breeding sites; suggests for changes in the ecosystem in an endemic malaria area; may influence mosquito reproduction patterns; and produce changes in malaria seasonality (Fábio et al., 2011). Dams in Brazilian Amazon were the only positive breeding sites during the wet season as no larvae were found in the river and larval collections from all sites in the river bed were positive for *An. darlingi* immature stages in the dry season where the riverbed formed puddles, which were readily colonized by mosquito larvae of various species (Fábio, 2011).

Agricultural expansions in Northern and River Nile States will attract labor force mostly, from central and western Sudan which are Mesoendemic areas of malaria endemicity. This will significantly influence both States since the importance of migration in the spread of various diseases in tropical Africa has been well documented (Alredaisy and Davies, 2003), and various facets of the effects of migration on the spread and incidence of malaria have been examined seriously since the 1950s (e.g., May, 1958; Prothero, 1961; 1965; 1994; 2001; Meade, 1976; Singhanetra, 1993). The tradition movement of east-wards by western Sudanese and West Africans along the savannah grass road and nomadic migration with the seasons are very significant in the spread of malaria in Sudan. This has been confirmed in the Gezira scheme where the long –standing contention among the Gezira tenants and these migrants were an important factor in this disease (Elhassan, 1998). That was due to agricultural extension into the fertile lands of Sudan following the establishment of Geziera Agricultural Scheme in 1924.

Agricultural expansion and building of dams in Northern and River Nile states are expected to change malaria endemicity from Hypoendemic to Mesoendemic. This will make both States and central Sudan a one continuous geographic area of Mesoendemic malaria, and might extend to include Mediterranean land. This will result in one continuous Mesoendemic zone of malaria extending from interior Africa up to the Mediterranean. According to Simon et al. (no date) preliminary analyses of existing endemicity maps indicate the probable extent of malaria infection risk outside the AFRO area, and particularly in the SEARO region, conclusions that remain strong even under very optimistic scenarios of endemicity reduction.

Towards a model for control of malaria in arid Sudan:

The proposed model (Figure 5) consists of six working integral parts to achieve its proposed purposes. Complementary programs of eradication of malaria in central Sudan have to be integrated with those in the new agricultural openings*.* The old experience of malaria control in central Sudan was evident where Khartoum town itself was declared free of malaria from 1904 during the Anglo-Egyptian Condominium. *Environmental policies and plans* which commensurate with “the extent of the malaria problem connected with irrigation in arid zones does not depend as much on the climatic conditions or the potentiality of the vector in establishing malaria transmission as on man-made disturbance of the ecologic balance” (Farid, 1977) were integrated in the model. This integral part agrees also with that, *Anophelesgambiae*, inhibits diverse environments including dry savannas, where surface waters required for larval development are absent for 4-8 months per year and under such conditions *Anophelesgambiae* disappears. It furthermore agrees with the fact that, whether *Anophelesgambiae* populations survive the long dry season by aestivation or are re-established by migrants from distant locations where larval sites persist has remained an enigma for over 60 years this is important because fragile dry season populations may be more susceptible to control (Lehmann et al., 2010). The model integrated *commensurate development of preventive infrastructure, public hygiene and reasonable housing* with vast increase in agricultural expansion. Such vast increase is needed because achievement of food security for the rapid growing population of Sudan and the need for provisioning of jobs opportunities for the growing working youth are vital. The model also, considered *environmental health policies and plans and community awareness on malaria prevention and fightinghave to be integral part of agricultural development programs.* This is very important as community participation in environmental management became beneficial in recent times. The model also considered that the impact of epidemic in general could be controlled or minimized by *prediction and improved prevention through timely vector control and deployment of appropriate drugs*. This could be more enhanced by malaria Early Warning Systems as a means of improving the opportunity for preparedness and timely response (Kopec et al., 2005). In addition, *changing of traditional cropping system* might help curbing malaria in arid Sudan since there is a concern that crop irrigation that results in increased numbers of vector mosquitoes will lead to a rise in malaria in local communities (Ijumba et al., 2002), and the experience of rice irrigation was associated with less malaria than alternative agricultural practices, despite the considerable numbers of vectors produced in paddies. As the majority of the agricultural development is in arid Sudan is privately owned farms, particularly the Arabs, *their incorporation into the achievement* of the integrated parts of the proposed model is vital.

This proposed model here, if successfully implemented could be transferred to other areas of Sudan and to other similar environments worldwide.

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3

Typhoid Fever in Sudan: Some Geographic and Time Considerations From 2000-2008

3

Typhoid Fever in Sudan: Some Geographic and Time Considerations From 2000-2008

Typhoid enteric fever is a waterborne disease that is transmitted through the faecal-oral route following the consumption of contaminated water and food stuff with Salmonella typhi or typhoid bacillum or urine from an infected person or carrier (Royal Tropical Institute, 2010). It may live and multiply in the gall bladders of carriers whose health it does not affect. It can survive in water for 7 days, in sewage for 14 days and in ice cream for 1 month and it is destroyed by temperature greater than 50 ^{0}C (Punjani, et al., 1997). The incubation period ranges from 8 to 28 days, depending on inoculums size and immune status of the host- i.e., vaccination coverage of the host. Transmission can also occur directly in families through contact with a new or chronic carrier. It may also be transmitted indirectly through improperly washed fruits and vegetables if consumed raw. About 90% of the cases are transmitted indirectly (Lucas, 1993). Flies act as passive vectors due to fluid contacts with their legs, when they consume between latrines and kitchens. Typhoid is recognized by the sudden onset of sustained fever, severe headache, nausea and severe loss of appetite. It is sometimes accompanied by a hoarse cough and constipation or diarrhea. Typhoid symptoms resemble those of malaria, typhus; and other enteric diseases, therefore it is often not readily diagnosed.

Man is the only known reservoir for the typhoid bacilli This may be in the form of overt case of the disease, an ambulatory ‘missed’ case or symptom-less carrier. About 2-4% of the out-patients become chronic carriers of the disease and in most parts of the world faecal carriers are more common than urinary carriers. The carrier state is more common among persons infected during middle age especially females (Luca, 1993; Bensenson, 1975). Carriers are either chronic or convalescent. A chronic carrier is defined as a person whose stool is positive for Salmonella for at least a year continuously following an episode of the disease. A person with positive stool cultures without any history of the disease can spread infection to others or cause contamination.

Chronic carriers are a threat to the community around them (Sonhani et al., 1998). Middle-aged women are common carriers because of their care for others like household members or young children who might be infected persons or carriers.

Its prevalence is determined largely by hygienic standards and practices among individuals and communities and has been used as an indicator to the level of community hygiene. Typhoid is an internationally as well as locally notifiable disease because of its epidemic potential (WHO, 1997). Infection with Salmonella Typhi causes an estimated 20 million cases of typhoid fever and 200,000 deaths annually worldwide (PhysOrg., 2010).

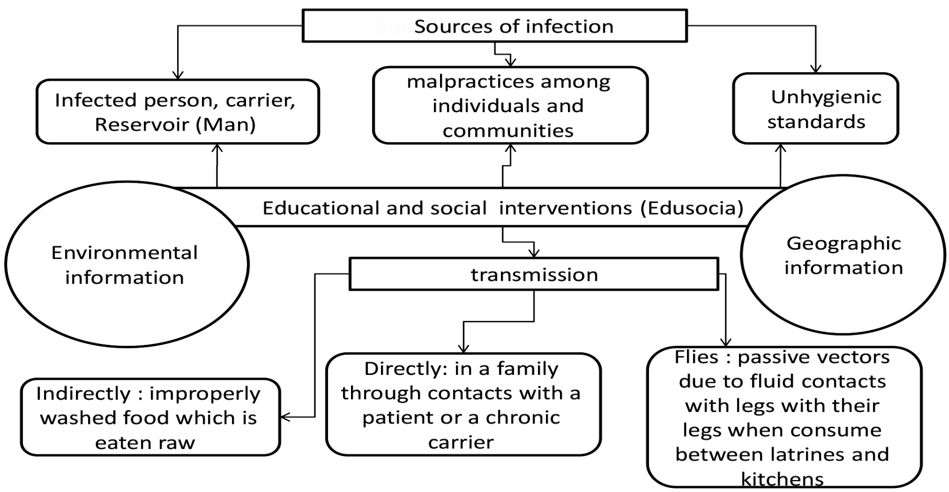
Typhoid is a disease, which has been affecting people since time immemorial without being specified because its symptoms resemble those of malaria, typhus fever and dysentery. Prior to its first identification by Gerald in 1836 and then by Stewart in 1840 and lastly by William Jenner in 1851 who was the first successfully made a definition of the disease, it was difficult to establish a historical diagnosis prior to that time. However, scholars working on the history of Jamestown, Virginia (USA) believe a typhoid outbreak was responsible for the deaths of over 6,000 settlers between 1607 and 1624. In the war against South Africa in the late nineteenth century, British troops lost 13000 men to typhoid, as compared to 8000 battle deaths (WHO, 1997). Nonetheless, it looks like today the incidence may still be as high as it was in the past but today the case-fatality rate has dropped dramatically. The typhoid outbreak in Gabon has spread to the capital Libreville, which has been grappling with water shortages for two weeks (UN, 2010). In many parts of Kenya typhoid fever is prevalent, especially in Nyanza and Eastern provinces. Poverty, congestion and unhygienic living conditions have worsened the situation. In Nyanza, lack of treated water, ignoring precautionary and preventive measures have made the province a typhoid-ridden region (Onyango ,2002).An outbreak of typhoid has struck the Jirgital District in the Rasht Valley of Tajikistan. A latrine-contaminated water source is the suspected source of the outbreak (, Medicins Sans Frontieres, 2002).Crump et al,(2003) estimated that the incidence of typhoid fever was 13/100,000 persons per year in Bilbeis District, Egypt.

In virtually all endemic areas, the incidence of typhoid fever is highest in children 5-19 years of age. Data mainly from Africa, Asia and Latin America show that typhoid fever continues to be a public health problem with schoolchildren aged between five and 15, disproportionately affected. In some endemic areas, children under 5 years show incidence rates similar to, or exceeding those of school-age children. In Ashanti region the estimated incidence of typhoid was 205 / 100,000 children who were 4 to 5 years old (Graphicghana, 2010). In addition, Ochiai, et al (2003) indicated that a total of 21,874 episodes of fever were detected. The annual typhoid incidence (per 100,000 person years) among age group 5-15 years varied substantially between countries, being high in India and Pakistan, intermediate in Indonesia, and low in China and Viet Nam. Here, the potential relationship between mother and child is evident. Long exposure of a child to his mother, who might be infected or a carrier, transmit typhoid. This is particularly when mothers are fully responsible of child growing, even if they work laboriously. These findings highlight the considerable, but geographically heterogeneous, burden of typhoid fever in endemic areas and underscore the importance of evidence on disease burden in making policy decisions about interventions to control this disease.

The Ministry of Health Statistics in Sudan report that the primary risk factors for typhoid are physical conditions, population factors, illiteracy, inadequate water supply and low government expenditure on health sector. The purpose of this study is to highlight geographic and temporal variations of typhoid in Sudan from 2000-2008. The paper proposed "ESENGEO" model (figure 1) which focuses on sources of infection and modes of transmission of typhoid. The "ESENGEO" model shows sources of infection of typhoid as including unhygienic standards, malpractices among individuals and community as well as infected persons, carriers and reservoirs. Similarly, the model depicted direct and indirect modes of typhoid transmission, as well as the role of flies. The main objective of the "ESENGEO" model is to assess and reduce infection and transmission of typhoid in a community. The importance of "ESENGEO" comes from its simplicity, its potentiality to deal with the available resources at the community level and its affordability to be applied to many infectious disease transmission cycles in other geographic setting. The components of "ESENGEO" work together to initiate power (arrows in figure 1) focusing on source of infection and modes of transmission of typhoid. "ESENGEO" works like an open ecosystem having inputs, processes and outputs. The inputs are the educational, societal, environmental and geographical information on typhoid. The processes are the impact of these inputs on typhoid in a community. The outputs are the assessment and reduction of typhoid.

Education is important in the assessment and reduction of typhoid. Educated society will, of course, have knowledge about personal hygiene, environmental sanitation, typhoid transmission and infection; however, additional health education will also help people to become aware about how to avoid the disease through prevention and control efforts. Use of valuable inherited culture of a society on infection and curing of diseases are beneficial. In addition, society capacity building by collective work, civil or voluntary organizations could work to assess and combat typhoid. Since typhoid is highly linked with the physical environment, where temperature, rainfall, flooding or aridity may determine its incidence, morbidity, seasonality and breeding of insects, however the provision of such necessary databases is substantial for assessment and prevention of typhoid. Geography provides information on location, population mobility and density, congestion, geographic proximity and their role in typhoid infection and transmission. Typhoid prevalence rates have geographical scales worldly, continently, regionally and nationally. Determination of such geographic differences on typhoid will provide database for space dealing with typhoid. The application of "ESENGEO" in Sudan will further be outlined after reviewing the results of this paper.

Figure (1): ''ESENGEO'' model for typhoid assessment and reduction in Sudan



Sudan is located in northeast Africa, bordered by 9 countries and divided into 16 states (figure 2). The population of northern Sudan was 30,894,000 million in 2008, with an average of 29,021,000 million and annual change by 2% for the period 2000-2008 (table 1). Population of northern Sudan distributed by regions and by states will constitute the population under study for typhoid fever in this paper as was illustrated by typhoid prevalence rates in tables 2 and 3.

Official statistics published by National Ministry of Health in Sudan were used to analyze typhoid space-time behavior from 2000-2008. Sudan was treated nationally, regionally and administratively as states. Regional agglomeration was done by including many administrative states into one mega geographic region where 4 regions were distinguished. They were the northern, central, eastern and western regions. This division had followed the general mental geographic map of Sudanese about space division of their country.

The prevalence rates of typhoid were calculated by dividing number of out out-patients by the total population at risk and multiplying by 1,000. Prevalence rates were calculated for the national, regional and state levels. Regional prevalence rates were calculated by the sum of prevalence rates by the entitled states of a region and then taking the average. Time trends of typhoid were measured numerically, proportionally and directionally to depict yearly changes and presented in graphs. Three year running prevalence rates were also calculated for the space scales indicated earlier. ANOVA test is done to compare three years running prevalence rates of typhoid by major regions of Sudan to establish significant differences at 0.001 level when the H_0 is rejected, calculated F- value is greater than the critical value. Proportional change of typhoid is shown by index numbers by Sudan states. Actual figures were converted to percentages by taking the year 2004 as base year to facilitate comparison between all figures. Ranking correlation "Spearman's correlation" between % of change in population and % change in typhoid prevalence rates by Sudan's states were calculated using the formula: $r = 6 \sum d^2 / n(n^2 - 1)$, where $\sum d^2$: sum of squares of differences between population and prevalence rate for each state and n = number of values.

Figure 2: Sudan location

Source: https://www.google.com/search?q=sudan+location

Typhoid out-patients records in northern Sudan are successively increased (table 1). This was with a general annual average of 44,663 out-patients. The population during this time period is also increasing. Its general behavior distinctively shows slow increase between 2000 – 2004, steady increase between 2004 -2007 and sharply increased up to 2008 (table 1). The calculated year by year % of change in typhoid out patients similarly depicted fluctuating behavioral pattern for that period. The calculated difference between average annual typhoid out-patients % of change and average annual population % of change is imperatively high by 19.9%.

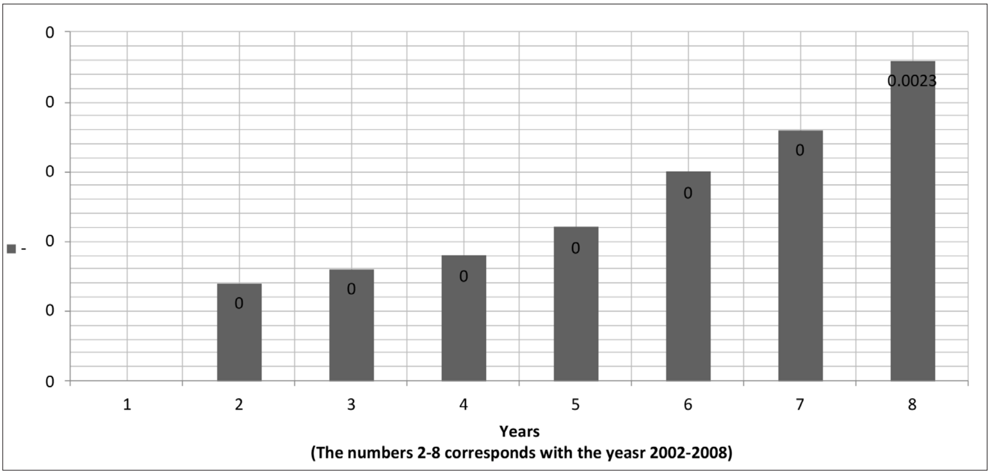
Table (1): Population, typhoid out-patients and the calculated
prevalence rates in northern Sudan, 2000-2008

year	(population (000	out-patients	prevalence rate per 1,000
2000	26046	16035	0.6
2001	26840	18865	0.7
2002	27569	21679	0.8
2003	28363	25166	0.8
2004	29146	38786	1.1
2005	29949	48053	1.3
2006	30767	66436	2.1
2007	31623	77480	2.0
2008	30894	89473	2.9
average	29,021	44,663	1.4

Source: Annual health statistics reports, 2000-2008, Ministry of Health, Sudan. The prevalence rate was calculated by the Author.

Time behavior of typhoid was evaluated by calculating the 3 years running prevalence rates which smoothed the curve to depict a steady increase of typhoid in northern Sudan (figure 3). So, it appears that increasing population is accompanied by increasing typhoid, which may reflect educational, societal, environmental and geographical situations in the country. Sudan has a heterogeneous physical environment with different climates and habitats extending from near the equator to the Sahara Desert. In this physical environment live different societies having different local cultures, although the majority is Muslims. Education levels vary widely in the country and geography apart many societies living there. These characteristics have, of course, substantial influence on space-time behavior of typhoid in Sudan.

figure (4): 3 years running prevalence rate of typhoid in Sudan: 2000-2008



Typhoid at regional level:

Regional agglomeration (section 2) had distinguished northern, central, eastern and western regions in the Sudan. Northern region included northern and River Nile States. Central region included Khartoum, Sinnar, White Nile, Blue Nile and Gizira states. Eastern region included Red Sea, Kassala and Gedarief states. Western region included north, south and west Darfur states in addition to northern, southern and western Kordofan states. Based on figure 2 the geographical regions of Sudan were represented by figure 5.

Based on data of typhoid prevalence rate by state and regional agglomeration indicated in section 2, the prevalence rate of typhoid was calculated by regions (table2). Northern region depicts a fluctuating pattern while central region shows somehow an increasing pattern except being decreasing in 2008. Eastern region is fluctuating while western Sudan region is stable for three successive years (2000-2002) and then steadily increasing during the remaining of the period (2003-2008). Small differences exist between eastern and western region on average values of the prevalence rates while they are remarkably different than northern and central region, which were almost close on the two values. However, ranking of regional typhoid prevalence put central region first, then the northern, eastern and western region respectively.

The 3 years running prevalence rates of typhoid were calculated by Sudan regions (figure 6). Regional differences between central region and other regions of Sudan might refer to population size, inclusion of many states into that region, although they were less than those included into western region and to data limitations that many states had no records between 2000-2003 which all might have affected the results. In addition, educational, societal, environmental and geographical difference are also important as ''ESENGEO' model had proposed.

These regional differences are statistically tested by the analysis of variance (ANOVA). There are significant statistical differences at .001 level in typhoid between and within Sudan regions. The calculated ‘'F - ratio'' is greater than all other critical values at all other significance levels. The occupation of first rank by central region in typhoid has environmental and socioeconomic implications. In this region there are remarkable rainfall amounts, clayey soil and the majority of Sudan's population live. Spread of education makes people aware of diseases to visit doctors and attend hospitals, which are reflected on the official records of typhoid. Presence of big urban centers like Greater Khartoum, Medani and Kosti into this region, have their own environmental health problems. Acceptance of rural migrants from peripheral regions might raise typhoid records since migrants are mostly illiterate, poor and lacking personal hygiene. Western region occupies the tail of ranking, which might refer, in addition to absence of statistical records, also to spread of illiteracy, political instability and environmental problems where they are mostly of arid and semi-arid environment.

figure (5): Geographical regions of Sudan

Table (2): Prevalence rates of typhoid by regions of Sudan

years	northern	central	eastern	Western
2000	0.6	0.1	0.3	0.01
2001	0.02	0.8	0.03	0.01
2002	0.2	0.8	0.01	0.01
2003	0.4	0.9	0.2	0.07
2004	1.4	1.5	0.3	0.08
2005	1.1	2.6	0.1	0.1
2006	0.9	3.0	1.6	0.1
2007	2.3	3.5	0.4	0.3
2008	2.9	2.2	0.9	0.4
average	1.1	1.7	0.4	0.1
rank	2	1	3	4
Per 1,000 population				

Typhoid at state level:

Calculations of the distribution of Sudan population by states depict an uneven distribution. Ranking states by % of change in population for 2000-2008 distinguishes firstly, the arid axis of rapid population change includes Red Sea area and western Sudan and secondly, the wet axis with somehow slow population changes around the Niles including central and northern states. Environmental, socioeconomic and political factors appear to be responsible for that. Table 3 shows prevalence rate, a state rank in addition to index numbers of typhoid by states

Table (3): Typhoid prevalence rate (PR) and index numbers (IN) by Sudan states,2000-2008

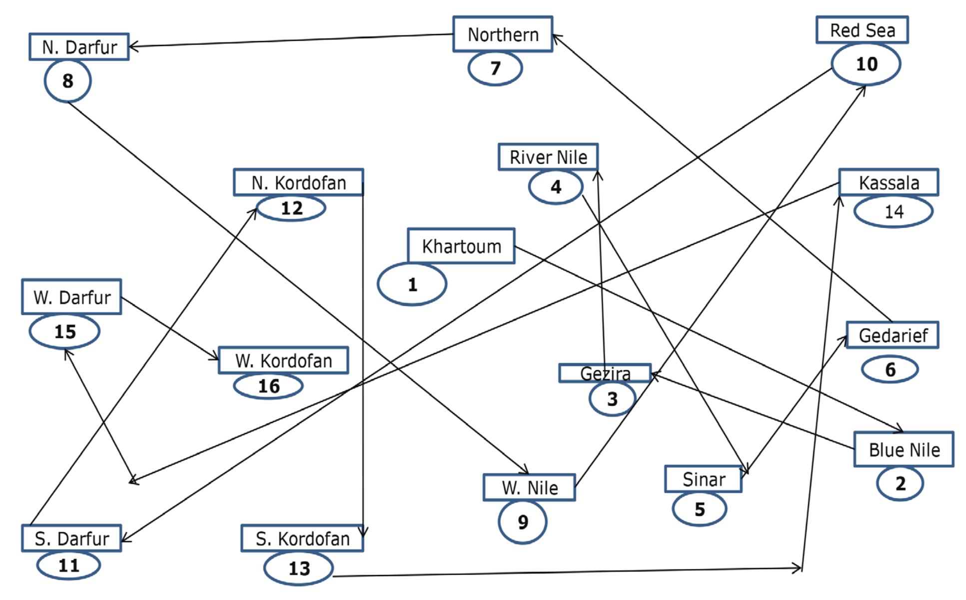
Years / States		2000	2001	2002	2003	2004	2005	2006	2007	2008	Avrg.	Rank
Northern	PR	0.04	0.05	0.2	0.6	1.9	1.4	1.0	2.5	1.5	1.02	7
	IN	2.0	2.8	11.1	33.3	100	77.6	55.5	141.2	86.6		-
River Nile	PR	0.6	NA	0.2	0.2	0.9	0.8	0.9	2.2	4.3	1.3	4
	IN	16.8	0	17.9	23.7	100	85.9	107.9	246.9	530.6		-
Khartoum	PR	0.3	3.4	3.7	3.7	5.2	5.1	6.7	7.9	4.2	4.5	1
	IN	47.1	58.7	66.6	67.9	100	102.5	137.6	170.4	76.1		-
Gizira	PR	0.3	0.5	0.5	0.9	1.2	2.5	2.3	2.7	3.4	1.6	3
	IN	21.6	34.2	41.8	75.1	100	216.3	198.4	237.4	262.4		-
White Nile	PR	NA	NA	0.02	0.1	0.2	0.3	0.1	0.5	1.2	0.3	9
	IN	0	0	11.5	39.8	100	206.5	97.3	322.9	821.1		-
Blue Nile	PR	NA	NA	NA	NA	0.9	5.0	5.1	4.0	0.7	3.1	2
	IN	0	0	0	0	100	524.1	549.6	447.7	787.3		-
Sinnar	PR	NA	NA	NA	NA	0.08	0.3	0.8	2.6	1.7	1.09	5
	IN	0	0	0	0	100	388.8	1,049	3,373	2,020		-
Red sea	PR	0.6	.005	0.02	0.3	0.6	0.2	0.1	0.1	0.3	0.24	10
	IN	99.3	0.97	4.12	53.4	100	37.6	24.3	19.7	8.7		-
Gedaref	PR	0.2	0.1	NA	0.1	0.2	0.2	4.7	0.8	2.1	1.05	6
	IN	87.6	46.1	0	62.1	100	75.4	2,379	359.0	861.0		-
Kassala	PR	.005	0.01	0.01	0.1	0.1	0.01	0.03	0.3	0.2	0.08	14
	IN	3.63	7.3	13.6	18.8	100	8.6	27.7	209.1	195.5		-
S. Darfur	PR	NA	.003	NA	NA	0.1	0.2	0.3	0.3	0.5	0.23	11
	IN	0	2.4	0	0	100	148.2	252.5	294.8	453.7		-
N. Darfur	PR	NA	NA	0.01	0.2	0.2	0.2	0.4	0.9	1.0	0.4	8
	IN	0	0	11.2	98.5	100	112.6	239.4	662.1	791.8		-
W. Darfur	PR	0.04	0.02	0.05	0.07	0.09	0.2	0.05	0.08	0.04	0.07	15
	IN	0	0	23.5	139.5	100	103.7	0	0	0		-
S. Kordofan	PR	.005	0.01	0.02	0.01	0.03	NA	0.02	0.05	0.6	0.09	13
	IN	11.6	32.6	60.5	32.6	100	0	79.1	230.2	1,802		-
N. Kordofan	PR	0.02	0.03	NA	0.1	0.05	0.1	0.09	0.2	0.4	0.1	12
	IN	46.2	52.7	0	196.7	100	237.4	254.9	541.7	1,313		-
W. Kordofan	PR	NA	NA	0.01	0.09	0.06	0.06	NA	NA	NA	0.05	16
	IN	0	0	23.5	139.5	100	103.7	0	0	0		-

Source: calculated from Annual Health Statistical Yearbooks, 2000-2008. National Ministry of Health, Sudan.

Ranking states by the general prevalence rate of typhoid (table 3) distinguished some states with rates far exceeding those of whole Sudan (table 1). They included Khartoum and Blue Nile states. Some other states have rates far below the general prevalence rate of typhoid in Sudan such as the states of Kordofan and Darfur, Red Sea, Kassala and the White Nile states. However, states of Northern, River Nile, Gizira and Sinnar show very close rates to those of whole Sudan. In addition, the prevalence rate of typhoid by state revealed two separate groups of typhoid behavior over time. The first group has a fluctuating pattern of behavior and the second group has a steady increase in the prevalence rate. The first group includes Red Sea, Gedaref, White Nile, Blue Nile, West Darfur, north Kordofan, west Kordofan, Kassala, Sinnar states. The second group included Gizira, Khartoum, Northern, south Darfur, north Darfur, south Kordofan and River Nile states. However, proportional change in typhoid by states is shown by index numbers (table 3). For example, in Red sea state the index number 99.3 in the year 2000 gives an indication for decrease in typhoid by 0.97% than the base year 2004. Generally, pre the base year 2004 all states have lower percentage compared with after the base year period 2005-2008 with few exceptions in some years under study. Ranking correlation by states between % change in population and % change in typhoid prevalence rate gives 0.01, which is positively very weak.

Calculations of the three years running prevalence rates by states distinguished two major groups of spatial distribution of typhoid. The first group showed continuous increase in typhoid and centered around central and western Sudan. It included 9 states out of 16. They were the states of Khartoum, Gizira, Sinnar, White Nile, Blue Nile, South Darfur, North Darfur, North Kordofan and Northern state. This axis, centered at Khartoum state, goes firstly westwards to include north Kordofan, north Darfur and south Darfur states and also goes southeastwards to include Gizira, Sinnar, Blue Nile and White Nile states. Its northwards extension included northern state, which was cut by River Nile state as it belongs to the other group. According to Gideon informatics (2010) typhoid rate in the Gizira in 1986 was 35 per 100,000 and 10.5% of persons were Widal-positive (*Salmonella typhi*). The second group included 7 states making up two distinctively separated pockets of a fluctuating pattern of typhoid in Sudan. Firstly, is the eastern pocket including red sea, Kassala and Gedarief states, which shortly goes westward to include River Nile state. Secondly, the western pocket including west and south Kordofan and south Darfur states. It was clearly apparent that geographic proximity had influenced distribution of typhoid within Sudan's states. There is one huge geographical area of typhoid distribution including central and western Sudan states. In addition to relatively smaller pockets included eastern and western Sudan states. It can be said that western Sudan states have the two types of distribution pattern of typhoid, which were continuously increasing and fluctuating. Calculations of the 3 years running prevalence rates of typhoid by Sudan states depict differences, which were accordingly ranked and plotted in figure (7). This figure considered Sudan's states as geographic points linked together by arrows decaying with increasing ranking. The arrow starts from Khartoum state (No.1) and wanders over Sudan states to settle lastly in west Kordofan state (No.16).

Figure (7): Spatial decay of 3 years running prevalence rates of typhoid within ranked points representing states of Sudan (2000-2008)



Discussion and conclusions:

The general results are that:-

1. Typhoid depicts steady increase in Sudan during 2000-2008.
2. Regional differences are remarkable between central region and other regions of Sudan.
3. Geographic proximity influenced distribution of typhoid within Sudan's states where there were contiguous states having typical pattern of typhoid behavior of either continuously increasing or fluctuating.
4. Ranking correlation by states between % change in population and % change in typhoid prevalence rates gives a value of 0.01 which is positively very weak.

These results illustrate geographic and temporal variations of typhoid prevalence rates by Sudan states. The reasons for such variations appear to socioeconomically, environmentally and geographically related. The states of high prevalence rates of typhoid were those of central Sudan and mainly Khartoum, Geziera and Blue Nile states. In these states major economic investment is found and consequently high population concentration and increase as well as somehow good per capita income. In Khartoum state where the Capital of Sudan is found, the rate of population increase was 4.92 in 1956, raised to 7.76 in 1973 and to 8.75 in 1983 to reach 13.7 in 1993 (MFEP, Population censuses of Sudan 1956 – 1993). Population mean density in Greater Khartoum was 8.8 in 1983 and number of persons per square kilometer in 1973 was 55.6 persons to increase to 85.5 in 1983 and to 169 persons in 1993. Khartoum state received 39% of internal migration in Sudan in 1983 and 45% in 1993 (MFEP, Population censuses of Sudan 1956 – 1993). The degree of urban primacy of Greater Khartoum has changed where in 1955 Khartoum had 4.7 times the population of the second-largest urban center in Sudan. By 1993 Census this had increased to 8.9 times (Davies, 2001). In these states also the big irrigated agricultural schemes are found, such as the Geziera and Rahad schemes as well as Sugar factories of Kenana and Asalia. Institutions of higher education like University of Khartoum and Geziera are found here in addition, to the central Government. Migration, natural increase in population appears to be responsible for the higher prevalence rates of typhoid in these states. Studies in Sudan have well documented the strong relationships between a disease prevalence and population mobility and migration, congestion such as that of cholera and malaria (Alredaisy and Davies 2003). However, basic health infrastructure provided does not match with increasing population in these states, although they recorded high in their share of hospitals, doctors and primary health units (Ministry of Health, statistical yearbooks 2000-2008).

The whole of central Sudan states have climatic conditions conductive to the spread of typhoid. In Khartoum state, for example, average annual rainfall of nearly 161 mm is confined to the three months of July, August and September. During these months the average daily temperature range from mean minimal of 25 ^{0}C to a mean maximum of 38 ^{0}C and relative humidity averages 55%. These climatic features provide excellent grounds for insects breeding and the potential for typhoid transmission These conditions are further exacerbated by clayey soil conditions and lack of proper excreta disposal systems. The other states with somehow low prevalence rates of typhoid, in addition to data limitations, have low populations, particularly western and red sea states. Although some parts of western Sudan have more rains than central Sudan, sandy soil conditions are effective in water penetration and were not excellent niches for insect breeding. Similarly, River Nile and Northern states are of desert conditions and low population density, which are mostly located along the river Nile. In these states, also the per capita income is expected to be low relative to central Sudan state.

This discussion on typhoid prevalence rates about Sudan states commensurate with the statistics of the National Ministry of Health for whole Sudan which related typhoid to physical conditions, population factors, illiteracy, inadequate water supply, less governmental expenditure on health sector. As for adult literacy rate for 15+ years old of the population in 2007 it was 49.9% distributed as 50.9% males and 49.9%. Percent of population with safe drinking water was 59.2% in 2006 where the expected percent of typhoid reduction provided the improvement of water supplies is 80% (Ciba formation 1974). In the year 2002 adequate excreta disposal facilities were available for only 31.4% of Sudan population. In 1999, percent of population for whom health care is available was only 70%. These are in situations where % of annual growth rate of the population was 2.53 between 2003-2007, natural increase rate per 1000 was 41.23 in 2006 and total fertility rate was 5.9 in 1999. These factors were not accompanied by increased development in the Health Sector. The percent share of the health sector from the total budget during 2000 was only 2.08; in 2004 it was 1.68; in 2005 it was 2.20, while the actual expenditure on Health Sector in 2007 was only 0.31%which is substantially lower than many other African countries including cite)Between 2000-2008 the number of hospitals increased from 309 to 395 with the addition of only 86 hospitals which averages that only 9 hospitals were added annually. The number of Primary Health Care Units (PHCU) for the same period reduced from 2558 to 2005, while number of Health Centers increased from 915 to 1398. The Sudan Ministry of Health (2008) also indicated that the ratio of doctors is 15.4 doctor per 100,000 population for each state, while it is 65.5 doctor per 100,000 population in Khartoum state. There are 6 states have less than 10 doctors per 100000 population and there are 4 states have less than 20 doctors per 1000000 population. These findings demonstrate the immediate need for additional resources to be allocated to the health sector in Sudan.

This research shows that the lack of basic infrastructure and human and physical conditions are strongly related to typhoid prevalence rates in Sudan. There are gaps for prevention of typhoid in Sudan which could be bridged by appropriate intervention. Such an intervention could be directed towards whole Sudan or towards the states of high prevalence rates. There are assumptions that there is need to educate people about typhoid but in reality, people are probably very aware of it but because of poor water and sanitary infrastructure and perhaps population density it is very difficult to prevent. This study could build a very strong case for prioritizing improved infrastructure in addition to educating people. This could be done by the incorporation of the *"ESENGEO"* model (figure 1) in order to assess and reduce typhoid infection and transmission in Sudan.

Building for prioritizing improved infrastructure will depend on high quality environmental and geographical information. Environmental information about typhoid in Sudan should include relevant data about timing of the rainy season and all related climatic characteristics at state and regional scales for appropriate planning for insects breeding control and the expected incidence of typhoid. Soil information should be introduced also. Geographical information should deal with population growth, increase, mobility, migration, density and concentration to detect hazardous areas. The provision of investment map of Sudan can forecast population future trends of movement and the consequent health results. Geographical and environmental information for the " ESENGEO" model can benefit in addition to this local information, from the available typhoid fever incidence data which has grown worldwide with efforts to improve disease surveillance and the initiation of population-based typhoid fever incidence studies. This is in addition to the advances in understanding of the age distribution of typhoid fever to allow for incidence rates measurement among narrow age cohorts to be more accurately extrapolated to the general population. The formalization of methods for the assessment of typhoid burden provides a framework for standardized methods (WHO, 2004).Because typhoid does not appear as a major disorder in the Sudan burden of disease estimates, national programs addressing child health and survival recognize typhoid fever prevention, there are needs for reliable epidemiological information on the burden and severity of the disease in populations at risk to be consensus on case definitions and diagnostic criteria and the appropriate mix of preventive strategies including carrier detection, water and sanitation interventions. Inclusion of disease management as a tool to increase quality of care, improve patient outcomes and control costs to reduce provider practice variation is a key aspect the " ESENGEO" model.The target populations and strategies for administration of use of vaccines for preventing typhoid should be used on a wide scale in "ESENGEO" as recommended by WHO (2001) but consciously enough since typhoid fever can, to a limited extent be controlled by use of vaccine (Borgman, 1994) and the eradication of a carrier state can be difficult (Kumar, et al., 1999).

Educating people in Sudan about typhoid symptoms, treatment and prevention can be achieved by school subjects such as Geography and Biology and also by mosques, churches, adult education, media education, mobile cinema and distance education. In every state there are local broadcasting and television stations, a university and distance education centers. All these facilities can be used for educating people on typhoid. Educational technologies encompass electronic-based delivery methods and innovations in instructional design such as adult education, problem-based learning, and competency-based training. Distance learning includes synchronous methods, which link learners who are separated by geographic distance but allow for simultaneous interaction and asynchronous methods, which allow for interaction at different times (Muramoto et al, 2003). Health education to prevent typhoid include education about personal hygiene, especially regarding hand-washing after toilet use and before food preparation; use of safe drinking water; excluding disease carriers from food handling and antibiotic treatment.

Society capacity building on typhoid awareness in Sudan can positively be enhanced through religious and cultural norms encouraging personal hygiene and neighborhood sanitation where GOD rewards are endless, ethnoscience concerned with symptoms and treatment of typhoid, conscious use of herbal medicine and through traditional healers and curers capable to transfer correct information on typhoid to indigenous people. Activation of youth clubs and school vacations can provide volunteers working in typhoid campaign and prevention. The charity donations can help providing some sanitary materials for poor people, places of gatherings and suspected locations for insect breeding.

The application of the "ESENGEO" in Sudan works to assess infection and transmission of typhoid in order to decide on the appropriate methods by activation of the inputs, processes and outputs outlined by the "ESENGEO" is an important and timely public health intervention that has broad positive public health implications. The ultimate result is to reduce and eliminate typhoid in Sudan. However, the "ESENGEO" model can be applied for any other similar infectious diseases in Sudan and similar places in Africa, Asia and Latin America where infectious diseases are a major cause of high morbidity and mortality, especially among mothers and children who are most vulnerable in these countries

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4

Behavioral pattern of Tuberculosis in Sudan From 1995 through 2009

4

Behavioral pattern of Tuberculosis in Sudan From 1995 through 2009

Tuberculosis is an airborne debilitating chronic infection caused by Mycobacterium tuberculosis complex which is a small aerobic non-motile bacillus. It spreads through the air when people who have the disease cough, sneeze, spit or shout which is common in some cultures. The risk of infection is highest in cramped homes with little ventilation Most infections in humans result in an asymptomatic, latent infection, and about one in ten latent infections eventually progresses to active disease, which, if left untreated, kills more than 50% of its victims (Konstantinos, 2010). The World Health Organization estimates of the global burden of disease caused by TB in 2009 as 9.4 million incident cases (range, 8.9 million–9.9 million), 14 million prevalent cases (range, 12 million–16 million), 1.3 million deaths among HIV-negative people (range, 1.2 million–1.5 million) and 0.38 million deaths among HIV-positive people (range, 0.32 million–0.45 million). Most cases were in the South-East Asia, African and Western Pacific regions (35%, 30% and 20%, respectively) (WHO, 2010a). An estimated 11– 13% of incident cases were HIV-positive; the African Region accounted for approximately 80% of these cases (WHO, 2010a). Moreover, TB annual impact in the world is that in each year a total of 9 million new cases are added with more than 1 million cases among people living with HIV and half a million cases of MDR-TB and nearly 2 million deaths (WHO.2010). Also, it is indicated by (Médecins Sans Frontières Australia, 2008) that TB kills around 1.6 million people every year worldwide and another nine million are suffering from the disease and imposes a global burden of an estimated 8 million new cases. Tuberculosis kills approximately 1 million women per year and it is estimated that almost 1 billion women and girls are infected with TB worldwide (Thorson, et al., 2001). During adolescence rates begin to diverge and there is a much higher incidence in men than in women during adulthood. The relative risks reduce again in the older age groups.

In Sub-Saharan Africa including Sudan, approximately 300 per 100,000 are sickened annually by this disease. Around 110,000 people die of Tuberculosis every year and kills more people in the eastern Mediterranean region than other major communicable diseases (4). Sudan holds 8 - 11% of the TB burden in the eastern Mediterranean region (Elyas, 2007). In 2007, the incidence of all forms of TB at an estimated 243 cases per 100,000 population in Sudan (SNTP,2009). The estimated incidence of new smear-positive cases of 90 per 100,000 populations gives a total of 32,614 estimated new smear positive cases for a 33.6 million population of whole Sudan (SNTP, 2009).

The main objective of this paper is to identify time pattern of tuberculosis in Sudan, nationally, regionally and seasonally in order to assist with its reduction among the majority of poor Sudanese. The author proposes COPOVINNLIT after "combating poverty and innovating literacy" program for reduction of TB in Sudan (Fig.5). The COPOVINNLIT is considered integrative as each component is integral to other components in the program. The COPOVINNLIT depends on the ground that, in order to reduce TB in Sudan we have first to combat poverty and secondly, to extend literacy since TB is highly correlated with poverty and illiteracy. The COPOVINNLIT has social, economic and political strategies. These strategies have national, regional and local levels and have long, medium and short time periods.

Data is provided by the Sudan National Tuberculosis Program (SNTP) which usually includes new smear positive, relapses, and smear negative and extra – pulmonary cases of tuberculosis. New tuberculosis cases by sex and age structure and seasonal distribution of tuberculosis cases by quarter a year are confined to the years 2003-2007 due to lack of data. Data for southern Sudan covers up to 2007; Data for Sudan population is obtained from publications of United Nations, World Bank, and Central Bureau of Statistics of Sudan. Regional population data is obtained from Annual health reports of Ministry of Federal Health of Sudan.

Time trends for tuberculosis are measured numerically, proportionally, and directionally to depict yearly and seasonal changes by prevalence rates which are calculated by dividing the number of tuberculosis cases by total population and multiplying by 1,000. Proportional change of tuberculosis is shown via index numbers for Sudan and by regions; actual figures were converted to percentages by taking the year 2000 as the base year to facilitate comparison across all figures. Seasonal distribution of tuberculosis included Winter (January – February and March); Spring (April, May and June); Summer (July, August and September); Autumn (October, November and December). The standard deviation is calculated for national and regional distribution of tuberculosis by seasons. General trend line is also calculated for the periods 1995-2001 and 2002-2009 by taking the average for each period against the mid - year 1997 and 2004 respectively.

Regional agglomeration was carried out by including many administrative states in each of five geographic regions: the central, northern, eastern, western and southern regions. This regional division follows the general mental map held by Sudanese as to the spatial division of their country. Pyramid of new tuberculosis cases in Sudan, 2003-2007 was established by putting males versus females into the vertical axis corresponding to percentages in the horizontal axis. Spearman's rank correlation between population and tuberculosis 3 years running prevalence rates by regions was calculated as $r = 1 - 6 \sum d^2 / n (n^2 – 1)$,where $\sum d^2$ is the sum of squares of differences between population and prevalence rate for each region and *n* is the number of regioThe result of this correlation is tested under 0.1 confidence level to see that the null hypotheses (that there are no statistically significant relationships in three-year tuberculosis prevalence rates between population and tuberculosis 3 years running prevalence rates by regions of Sudan) is rejected if the calculated *r* - value is greater than the critical value under the chosen confidence level. Chi- square is used to see type of regional dispersion of new infected tuberculosis cases either they are uniform, random or clustered by using the equation: $x^2 = \sum(A – B)^2/ B$, where A is the observed distribution, B is the expected distribution. This value compared three-year prevalence rates of tuberculosis across major regions of Sudan to establish significant differences at the 0.1 level.

Time behavior by national level:

Sudan is located in east Africa and surrounded by nine countries (Fig.1). Tuberculosis cases increased from 14,327 in 1995 to 22,097 in 2009 giving annual addition by 6.6% (table 1). It rapidly increased between 1995 and 1999, slightly fluctuated between 2000 and 2007 and decreased by 2008. Proportional change of tuberculosis (Fig.2) depicts that prior to 2000, tuberculosis continuously raised and was stable and continuously dropping up to 2008. Three years running means (Fig.3) depict steady increase from 1995 through 2000, then slightly decreased in 2001 to restart increasing up to 2006, thereafter tuberculosis declined. Tuberculosis prevalence rates (Table1) increased between 1995 and 1999 and then steady decreased thereafter. Yearly differences in prevalence rates are quite small.

Although Sudan population is increasing, tuberculosis prevalence rates are decreasing since 1999. The highest mean value of tuberculosis by seasons goes to Winter and the lowest to Summer with standard deviation values of 0.77; 57.9; 224.4 and 41.6 by seasons respectively. The lowest value of the standard deviation is close to the mean value of Summer, followed by Spring, Autumn and Winter. Sex - age groups show females age group of 0 – 14 as exceeding males by 8.29%. In the second group of 15-24, males exceeded females by 17.35% (Fig.4). From thereafter males recorded higher. The two age groups, 25-34 and 65+ of males, recorded the highest among all other sex-age groups contrasting similar female age groups. Tuberculosis prevails more among adult and old males and also more evident among the younger females. The females' age groups of 35-44 and 45-54 are close to the second age group of females. Seasonal distribution of tuberculosis distinguished the highest incidence during Spring while the lowest during Autumn. Differences are very small between males and females during Winter and Spring and slightly higher during Summer and Autumn. Seasonal infection of tuberculosis by sex is similar and differences are almost constant.

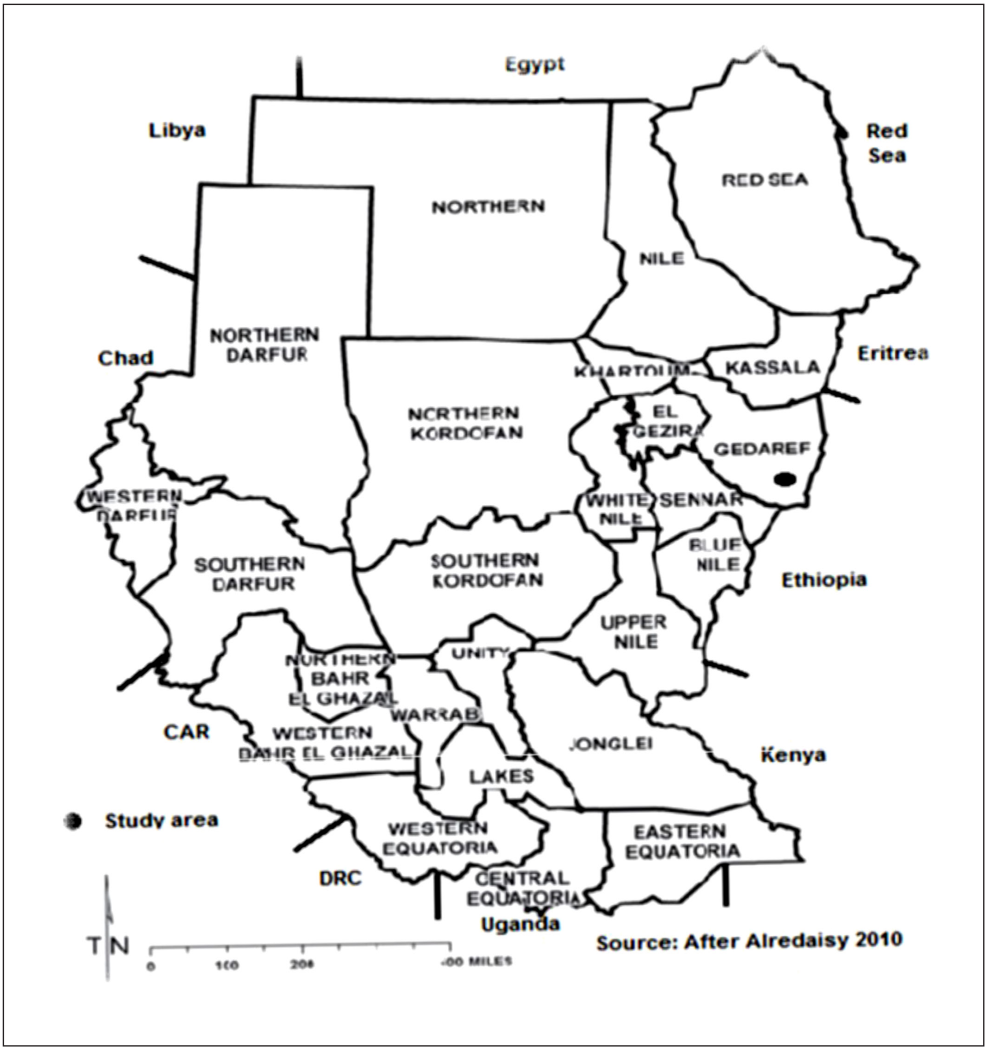


Fig. 1: Location and states of Sudan

Fig.3: Three years running means of Tuberculosis in Sudan, 1995 – 2009

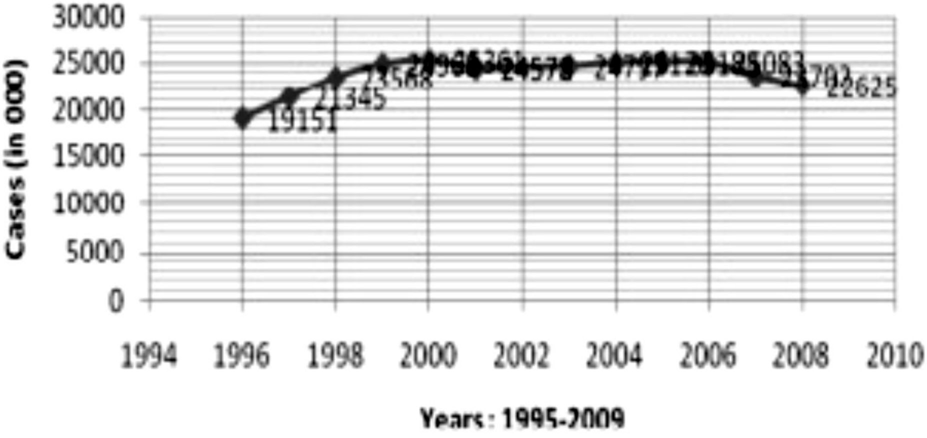
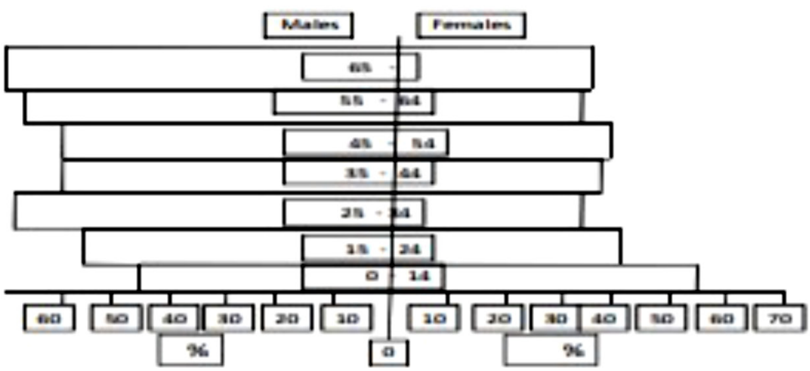


Fig. 4: Pyramid of new tuberculosis cases in Sudan, 2003-2007



Time behavior by regions:

Regional agglomeration distinguished northern, central, eastern, western, and southern regions. Regional ranking by mean of tuberculosis puts central region first then eastern, southern, western and northern regions. This ranking is also kept by central, northern and southern regions for the mean population while western and eastern regions exchanged their ranking position. The standard deviation shows great dispersion of tuberculosis in the central region ($\bar{x}$= 13,063 and SD = 1412.7. The northern region has closer values ($\bar{x}$= 963.73 and SD= 282.9), the eastern region has very sharp difference ($\bar{x}$= 4,054 SD = 689.69), the western region also has wide dispersion ($\bar{x}$= 2, 472 and SD = 593.01) and southern regions similarly depicted wide dispersion ($\bar{x}$ = 2,542 and SD =927.1). The calculated qui square value of 30,201 is far bigger than zero value confirming for disordered and clustered regional dispersion of new tuberculosis cases to agree with the standard deviation values. This is because of the observed excess clustering of new cases tuberculosis cases in central region of Sudan.

Regional proportional change of tuberculosis (table 2) distinguished central region during the pre-base - year period by steady increase with very small differences and in the post base - year period tuberculosis fluctuated with big differences between the years considered. In northern region, tuberculosis dropped during the pre-base - year period and fluctuated in the post base – year period. In eastern region, tuberculosis fluctuated for both pre and post base year periods. In the western region, tuberculosis raised sharply in the second year of the pre-base - year period, declined sharply and then remarkably increased showing very fluctuating behavioural pattern. In the post base - year period, western Sudan depicted fluctuating pattern. For the southern region, tuberculosis steadily increased and fluctuated in the pre base – year period and similarly fluctuated during the post base – year period.

General and three years running prevalence rates of tuberculosis (table 3) are decreasing in central, northern and eastern regions, regardless of very minor fluctuations. Western region has similar rates in the first three and second three consecutive years then raised spontaneously in 2006 and then dropped down closely to the previous rates. Southern region rates have fluctuated by general prevalence rates while the three years running prevalence rates are almost similar. The calculated value of Spearman's rank correlation between population and tuberculosis regional prevalence rates is 0.3, tested under 0.1 confidence level to give the critical value of 0.9. This last value is bigger than the calculated value (0.3) to enable the rejection of null hypothesis (H_o) that there is no relationship between regional population and regional tuberculosis prevalence rates and to accept by 99% confidence level that there is relationship between both. In the northern region more infections by tuberculosis occur during winter (28.2%) similar to southern region (31.2%) but contrasting central (26.7%) and eastern regions which are tending towards Spring (28.4). The lowest records are witnessed during autumn for all regions as 23.9% for central; 21.1% for northern; 21.9% for eastern, and 21.8% for southern except western Sudan (29.9%). Differences tuberculosis infection during the Spring and Summer are very close in northern (25.9% and 24.4%), western (25.8% and 24.8%) and southern (23.5% and 23.5%) regions while more differences are there in the central (26.7% and 24.9%) and eastern (28.4 and 24.3%) regions.

Table (2) Proportional change of T.B by regions of Sudan, 1995 – 2009

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Central	49.3	69.8	78.6	89.9	104.5	100	94.6	101.9	96.9	98.0	98.3	99.7	99.1	86.6	92.6
Northern	186.4	166.8	66.9	89.1	84.1	100	83.1	67.8	84.8	82.0	77.1	60.0	62.0	51.1	52.4
Eastern	29.5	86.9	88.9	103.1	116.5	100	89.8	98.6	102.8	99.3	88.3	86.3	90.5	92.7	92.6
Western	84.8	158.7	51.8	70.9	106.0	100	103.9	118.4	148.8	152.6	171.5	161.5	203.2	241.9	229.8
Southern	37.6	51.3	117.3	90.1	114.1	100	108.2	78.5	89.6	74.7	106.5	109.7	52.6	-	-

Table (3): Population, T.B. cases, prevalence rate and the three years running prevalence by regions of Sudan,1995-2009

Years	Population					T.B. cases					Prevalence rate					3 years running prevalence rate				
	C	N	E	W	S	C	N	E	W	S	C	N	E	W	S	C	N	E	W	S
2000	11399	1482	3655	9510	5035	14407	1095	4452	1763	3374	1.3	0.7	1.2	0.2	0.8	-	-	-	-	-
2001	11785	1588	3756	11753	5191	13634	910	3998	1833	3652	1.2	0.6	1.1	0.2	0.7	1.2	0.6	1.1	0.2	0.6
2002	12143	1593	3840	10002	5202	14695	742	4398	2087	2649	1.2	0.5	1.1	0.2	0.5	1.2	0.6	1.1	0.2	0.6
2003	12603	1568	3937	10255	5285	13959	929	4577	2624	3022	1.1	0.6	1.2	0.3	0.6	1.1	0.6	1.1	0.3	0.5
2004	13003	1596	4033	10515	5366	14124	898	4422	2691	2522	1.1	0.6	1.1	0.3	0.5	1.1	0.6	1.1	0.3	0.6
2005	13414	1624	4131	10779	5448	14160	844	3929	3024	3594	1.1	0.5	1.0	0.3	0.7	1.1	0.5	1.0	0.9	0.6
2006	13833	1652	4231	12271	5530	14365	657	3841	2847	3701	1.1	0.4	0.9	2.2	0.7	1.1	0.4	0.9	0.9	0.6
2007	14282	1680	4335	12546	5616	14272	679	4031	3583	1776	0.9	0.4	0.9	0.3	0.3	1.0	0.4	0.9	0.9	-
2008	12697	1819	4534	12864	8260	12476	559	4129	4264	NA	0.9	0.3	0.9	0.4	NA	1.0	0.4	0.9	0.9	-
2009	13112	1932	4742	13182	1040	13348	574	4123	4052	NA	1.0	0.3	0.9	0.3	NA	-	-	-	-	-
Mean	12,827	1653	4119	11367	5197	13944	789	4190	2877	3036	1.1	0.5	1.0	0.4	0.6	-	-	-	-	-
Rank	1	5	4	2	3	1	5	2	4	3	1	4	2	5	3	-	-	-	-	

Source: Population United Nations Population Division of Department of Economic and Social Affairs, World Bank, and Central Bureau

Tuberculosis is a real health problem in Sudan although our analysis showed its decreasing versus population increasing in the country. Estimated TB incidence per 100 000 population by country by WHO in 2009, put Sudan within the group range of 100-299, which includes countries like Chad, Mali, Mozambique, Tanzania, Madagascar, India, Pakistan, Afghanistan, former Soviet Union Republics including Russia, Malaysia and Ecuador. At the same time Sudan has less TB incidence than all African countries lying south of the equator and some others in Asia such as Myanmar and north Korea which lay within the range ≥ 300 incidence rate (WHO a,2010**).** This puts Sudan in a position similar to many other countries world widely concerning this major health problem. In Brazil there are about 57 million Brazilians are tubercular, placing Brazil among the 22 countries with 80 percent of cases worldwide (news.xinhuanet.com.2010). Generally, Brazil, ranks 14th on the list of 22 high-burden TB countries in the world and accounts for 31 percent of all TB cases in the World Health Organization's Latin American Region (usaid.2011). Similarly, Indonesia is more worser than Brazil which has the third highest rate of tuberculosis in the world and more than 90,000 people die from the disease every year (News.xinhuanet.com, 2011).

In the western Pacific region including countries like Cambodia, China, the Philippines and Vietnam, tuberculosis remains a major public health problem where more than 20% of the global burden of TB is found in that Region. In 2007, there were an estimated 1.9 million incident cases (109 per 100,000 population). Four countries (Cambodia, China, the Philippines and Vietnam) account for 93% of the total estimated incident cases in the Region (Van Maaren, 2010). Sudan is also similar to some Arab countries facing the same problem. A Sana'a University study has shown that there is a high rate of extra pulmonary tuberculosis cases among Yemeni tuberculosis patients, when compared to other Arab states (Thuria,2007).. Although Egypt is not on the World Health Organization list of 22 countries with a high tuberculosis burden, it is considered one of the high-burden countries in WHO's Eastern Mediterranean region (usaid.2011). The World Health Organization warned of the increasing rates of tuberculosis infection in Egypt in 2008 (flutrackers. com/forum,2011). Even more, some European countries are facing tuberculosis problem similar to Sudan. In England and Wales in the period 1988 to 1992, the notified cases of TB increase by 12 per cent (Barry,1999). Tuberculosis rates in some parts of the UK are at 'Third World' levels (News. bbc, 2002). Russia occupied the 11th rank in the list of 22 high-burden tuberculosis (TB) countries in the world (USAid.2011). However, Sudan contrasts Cuba which has an incidence rate of seven tuberculosis (TB) cases per 100,000 inhabitants, one of the lowest in the world. "This achievement is the result of the systematic monitoring and treatment programs developed by the health authorities after the triumph of the Cuban Revolution in 1959," (News.xinhuanet.com, 2011). Nonetheless, Sudan is better than South Africa which ranked fifth on the list of 22 high-burden tuberculosis (TB) countries in the world (usaid.2011).

The general behavioral pattern of TB is fluctuating in Sudan is indicating to a peak during Spring, males are more vulnerable to infection by tuberculosis than females and Central region ranked first among other regions of Sudan and has a peak of tuberculosis during Winter similar to the southern region.

There is spring peak in central and eastern regions while Autumn peak is noticed in western region of Sudan. These findings illustrate tuberculosis temporal and geographic variations in Sudan as well as socio-economically, environmentally, and geographically related situations. Poverty in Sudan is evident where 77.5% of population were on or below the poverty line (Ministry of Labor (MoL/ ILO).1997) and 75% of them were classified as poor (UNDP, 2005). Nutritional status of the majority of Sudanese is low particularly among younger children. Studying children less than ten years in western Kordofan revealed that they are stunting, underweight and malnourished (Alredaisy, et al., 2011). This agrees with higher prevalence rates of tuberculosis among 0-14 years old children in Sudan and similar to notifications of tuberculosis increase by 35% in the poorest 10th of the population in England and Wales (Law, et al., 1995).

Tuberculosis has grown steadily and becoming worse in Sudan due to migration for environmental, economic and political factors such as civil war in southern and western Sudan (SNTP,2009). Displaced people live in overcrowded conditions suitable for spread of tuberculosis as It has been found that 56% of African refugee children may be infected with intestinal parasites and there is potential that the "riskier" migrants may spread infectious disease to individuals (www.faqs.or., 2010). This points to the role of high population density in the spread of TB in Beijing (Amesh, 2008). Also, civil war in Sudan led to rife poverty, rampant malnutrition and lack of hygiene among displaced and migrants similar to Tiruvallur in Tamil Nadu (India), where irregular and incomplete treatment on account of migration is likely to increase the burden of TB (Jagga Rajamma, et al., 2007). This agrees with the role of immigration in Norway where the proportion of patients born outside Norway is increasing due to immigration from countries with high incidence of tuberculosis being infected in as children or adolescents infected before arrival (Norwegian Institute of Public Health, 2011).

Seasonal distribution of tuberculosis by regions of Sudan distinguished Winter peak In the northern and southern but, contrasting central and eastern regions which are tending towards Spring. The lowest records of tuberculosis are witnessed during autumn in all regions, except western Sudan. Differences tuberculosis infection during the spring and Summer are very close in northern, western and southern regions while more differences are there in the central and eastern regions.

In the northern and southern regions Winter peak of tuberculosis contrast summer peak in Hong Kong (Chi Chiu Leung; et al., 2005) while central and eastern region Spring peak conform with northern India (Thorpe, et al., 2004). Seasonal regional variations in Sudan go with monthly trends in Moldova, Mongolia, Uganda and Zimbabwe which were most marked in Mongolia with ambient temperature (Biggie, et al., 2009). Tuberculosis is more found among males rather than females which commensurate with Moldova, Mongolia, Uganda and Zimbabwe (Biggie, et al., 2009) and also with general data for Africa (World Health Organization (2006).

This study confirmed that females during early childhood are more vulnerable to infection by tuberculosis than males. This contrasts most countries where there is no significant difference in TB between males and females during early childhood and pre-adolescence (Ana Bierrenbach, 2010). Female TB patients tended to be younger than male patients. Patients from the high incidence, indigenous population in Delta Amacuro state in Venezuela were younger and had a nearly equal male: female distribution (Edgar, et al., 2009). Among tribal population of Car Nicobar in India, it was found that 95.8% of the children enumerated were tuberculin tested and read while 16.4% of children without bacille Calmette–Guérin scars were infected with TB. The prevalence of TB infection and smear-positive cases of TB increased significantly between 1986 and 2002 (Murhekar, et al., 2004).

Regional differences into tuberculosis have ranked central region first because it includes agricultural investments and the Capital city of Sudan which accepts large numbers of internal migration when, for example, the role of migration in the spread of malaria in Thailand is identified (Singhanetra - Renarg,1993). National and regional aspects of tuberculosis are associated with illiteracy, inadequate water supply, and low governmental expenditure in the health sector. As of 2007, the adult literacy rate (for the population aged 15+ years) was 49.9 % (50.9 % for men and 49.9 % for women). In 2006, 59.2 % of the population had access to safe drinking water. In 2002, adequate facilities for the disposal of excreta were available for only 31.4 % of Sudan's population, and as of 1999, health care was available for only 70 %. Population growth was not accompanied by proportional development in the health sector. In 2000, the health sector received 2.08 % of the total budget; in 2004, 1.68 %; and in 2005, 2.20 %, while actual expenditure on the health sector in 2007 was only 0.31 % of the total budget. The national average is 15.4 doctors per 100 000 population (Ministry of Health, Sudan. 2008).

Conclusions:

The results reported here indicated significant for TB at both national and regional levels in Sudan as a serious health problem. However, World Health Organization (WHO, 2010 b) states that "without dramatic increases in funding and political commitment between 2010 and 2015, it is estimated that over 50 million people will develop active TB; over 10 million lives will be lost to this preventable, curable disease; 4 million of them will be women and children; millions of children will be orphaned needlessly and over 2 million cases of MDR-TB will emerge for want of proper care". This is an important message for Sudan to work hard to reduce TB in the country. The author's proposed COPOVINNLIT program for reduction of TB in Sudan (Fig.5) can work with that.

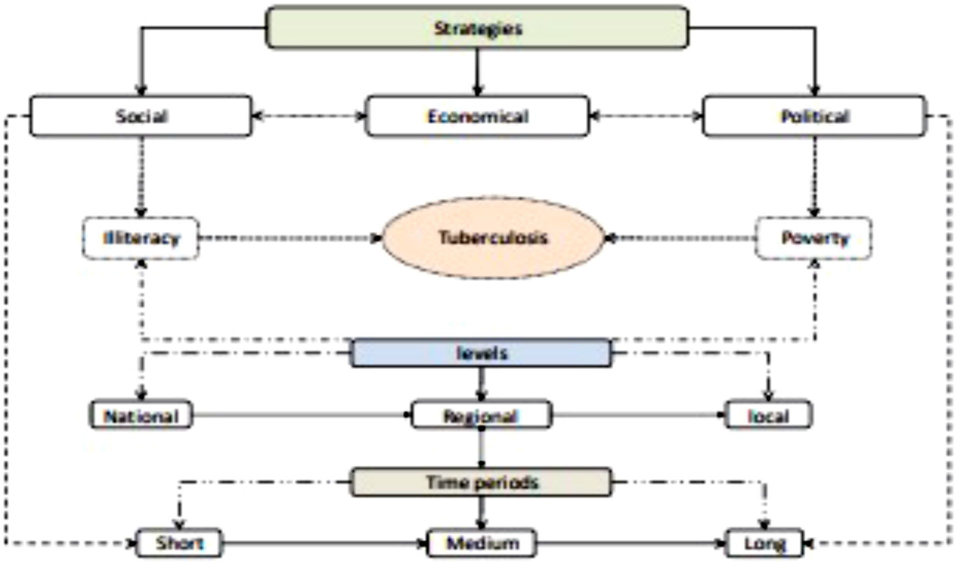


Fig.5: COPOVINNLIT program for reduction of TB in Sudan

The three integrated strategies outlined in the COPOVINNLIT program (Fig.5) target reduction of poverty and literacy innovation at national, regional and local levels. Targeting poor population in rural and urban areas is essential since they generally live in overcrowded houses and have low income. This is through sustainable socioeconomic and political developments which have to imply some TB program specific issues. Sustainable socioeconomic development should guarantee income generation to add to a community living standard, not only by national, regional and local economic projects, but also through micro finance for families in rural and urban areas. This will, of course, increase per capita and households' incomes which will improve nutritional, housing and general health conditions all will have good implications on the reduction of TB in Sudan. They have also to imply relevant specific TB issues related to community health awareness such early intervention programs of vaccination and primary information about TB to be diffused by posters and vocal media. Strategies for diffusion and innovation of TB information have to start from down to top by implying local concerned bodies first, who have ability to communicate with local people in simple language. Activation of volunteers, schools' children during school vacations and local TV and Radio stations are imperative to extend health education on TB with focus on a season with higher incidence of TB considering geographic and age – sex differences.

Moreover, political strategy has to work towards political stability, alleviation of wealth disparities in the country and enhance equitable distribution of GDP to reduce migration as a real factor into transmission cycle of TB in Sudan. Time schedule for each strategy can focus on applicable components of each strategy considering financial obstacles for implementation. They have to give priority to grass root communities. Up to date information should flow throughout authorized networks concerned with each strategy in order to cope with recurring situations of TB in Sudan. During each time period, specific targets of each strategy which are designed for a particular level have to be implemented.

Future work should concentrate on identifying risk factors contributing to seasonal/regional differences as well as better understanding how intervention programs would improve the rates of early detection and TB survival for all Sudanese. The application of the COPOVINNLIT model in Sudan can work to reduce TB in order to decide on appropriate methods through activation of the strategies at the various levels and through the time periods outlined by the model. However, the COOPVINNLIT model can also be applied for any other similar infectious disease in similar places in Africa, Asia, and Latin America.

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5

Predicting the Impact of Intercity Transportational Connections on Spatial Environmental Noise Pollution in Greater Khartoum

5

Predicting the Impact of Intercity Transportational Connections on Spatial Environmental Noise Pollution in Greater Khartoum

Sound can be described as a tiny variation in air pressure, detected by some receiver. Typical sound pressure amplitudes range from a few micropascals to a few hundred Pascals that fluctuate around atmospheric pressure (~101,000 Pascals). This variation in air pressure travels as a longitudinal wave, i.e., a compression wave, which propagates throughout the medium (air) at a velocity called the sound speed. In air at 20 °C, the speed of sound is about 344 m/s. In general, the tiny variation of pressure oscillates very rapidly in time around the atmospheric pressure. In the audio-range, these oscillations occur between 20 and 20,000 times per second. In other words, audible sound is made up of frequencies between 20 and 20,000 Hz (frequency). Very low tone corresponds with 20 Hz, while 20,000 Hz corresponds to a very high tone. Most noises are composed of many different frequencies. The traffic noise of motor vehicles is the most important type of noise to which people are exposed in their everyday life.

Noise pollution is defined as a displeasing human-, animal- or machine-created sound that disturbs the activity of human or animal life (Wikipedia 2009). World Health Organization has fixed 45 dB as the safe noise level for a city. According to W.H.O. which considers noise pollution to be the world's third worst after polluted air and water, exposure for more than eighty hours a day to sound in excess of 85 dB is potentially hazardous (IOL 2009). Cvetković1, et al (1997) produced the typical examples of levels of noise pollution as illustrated by Figure (1).

There are numerous models for the prediction of the contribution of public transportation vehicles in the total receipt of noise pollution in urban areas. These mathematical models are used to determine equivalent noise level (Leq) as the most representative physical variable quantifying noise emissions. The equivalent noise level corresponds to the sound pressure of a fictions stationary noise source emitting the same acoustic (audio) energy as the actual non- stationary (static) source. The equivalent continuous noise level in A-weighted decibels (dBA) is widely recognized as a stable descriptor of motor vehicle noise levels (Traulescu, S. 2007). It is recommended by many national and international regulatory agencies as a suitable index for use in motor vehicle noise assessments. Leq is known to correlate well with known effects of the noise environment on the individual and the public. The physical parameters to which Leq is correlated are, among others, traffic intensity, type of road surface, type of urban area, height of buildings, width of road, etc.

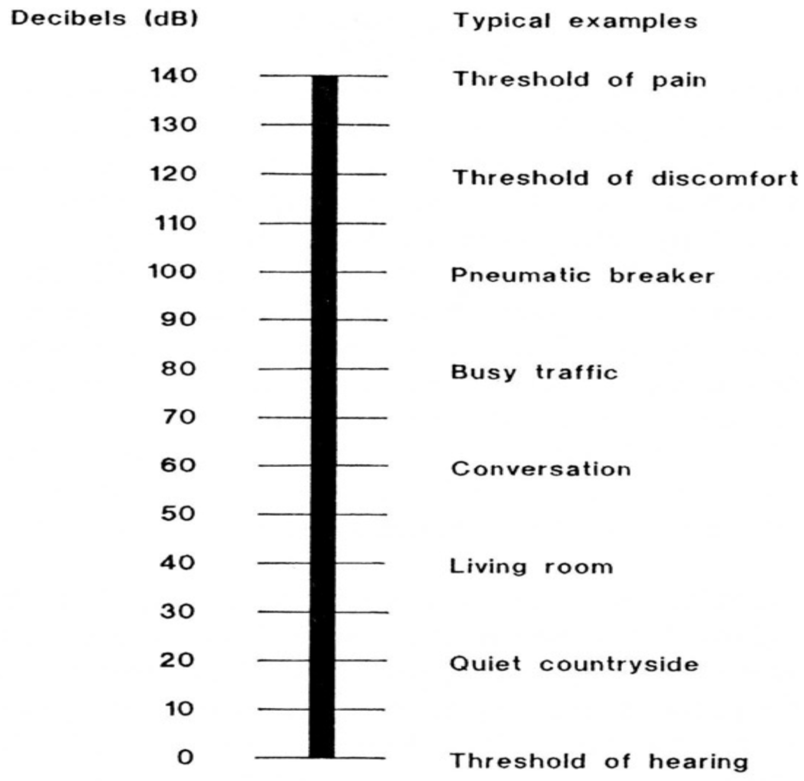


Fig. 1: Typical examples of levels of noise pollution

Source: D. Cvetković1, et al (1997)

Mathematical models for prediction of traffic noise usually extract the functional relationship between the parameter of noise emission, Leq, and measurable parameters of traffic and roads. The classical functional relationships have based on data measured through semi-empirical models, typically regression analysis. Of all the mathematical models available in literature, the ones which present this feature are those proposed by Burgess (1977), Josse (1972), and Fagoti. These functional relationships are essentially based on statistical analysis (i.e., regression techniques) and they are: -

$Leq = 55.5 + 10.2 \log Q + 0.3p - 19.3 \log (L / 2)$ (Burgess)

$Leq = 38.8 + 15 \log Q - 10 \log L$ (Josse)

$Leq = 10 \log (Nc + Nm + 8Nhv + 88Nb) + 33.5$ (Fagoti)

Here p is the percentage of heavy vehicles, L is the road width, Q is the total number of vehicles per hour, Nc is the number of light vehicles per hour, Nm is the number of motorcycles per hour, Nhv is the number of heavy vehicles per hour, Nb is the number of buses per hour. The total number of vehicles per hour, Q, is expressed as the equivalent number of cars and obtained, as before, under hypothesis that one heavy vehicle is equivalent to 6 light vehicles and one motorcycle to 3 light vehicles.

Although these correlations are nonlinear, they do not provide very accurate approximation of the trend followed by sound pressure level according to a certain number of physical parameters because any models itself includes the flow and composition of the road traffic which may be different than examined in urban areas.

Data on number of Mini Buses and transportation lines, confined to the year 2009, is collected from Department of Public Transportation & Petroleum of Khartoum state. This data concerns with Mini Buses with passengers' capacity of 15-25 persons. This is because Mini Buses are the main public transportation vehicles in Khartoum state, except few Taxi cars, and they are working for long hours per day. Determination of the main transportation axes is done by fieldwork during June 2009. Khartoum state is divided into main transportation axes emerging from central bus stations in each of the three towns of Khartoum, Omdurman and Khartoum north to reach the end points in each of the main transportation axes determined. Road width is estimated by travelling on the transportation network. Mean of number of journeys per day per vehicle is estimated as 20 journeys in a round trip journey on a mean time of 12 working hours per day as based on observation and interviewing with some Mini Buses drivers.

Because there is lack of data necessary to apply most of the models outlined in section 1 in the developing world, since they are mainly designated for the developed world where the data feeding them is so sophisticated and hence the results are highly reliable, this paper used the mathematical model for noise level prediction proposed by Josse which does not requires much data as the other models indicated earlier. This model states that:

$$Leq = 38.8 + 15 \log Q - 10 \log L$$

Where Q is the total number of vehicles per hour, L is the road width.

Statistical methods used for the analysis of data included the range, mean, coefficient of variation and the standard deviation as well as multiple correlation and analysis of variance to depict general situation and the statistically significant differences on noise levels in urban Khartoum state.

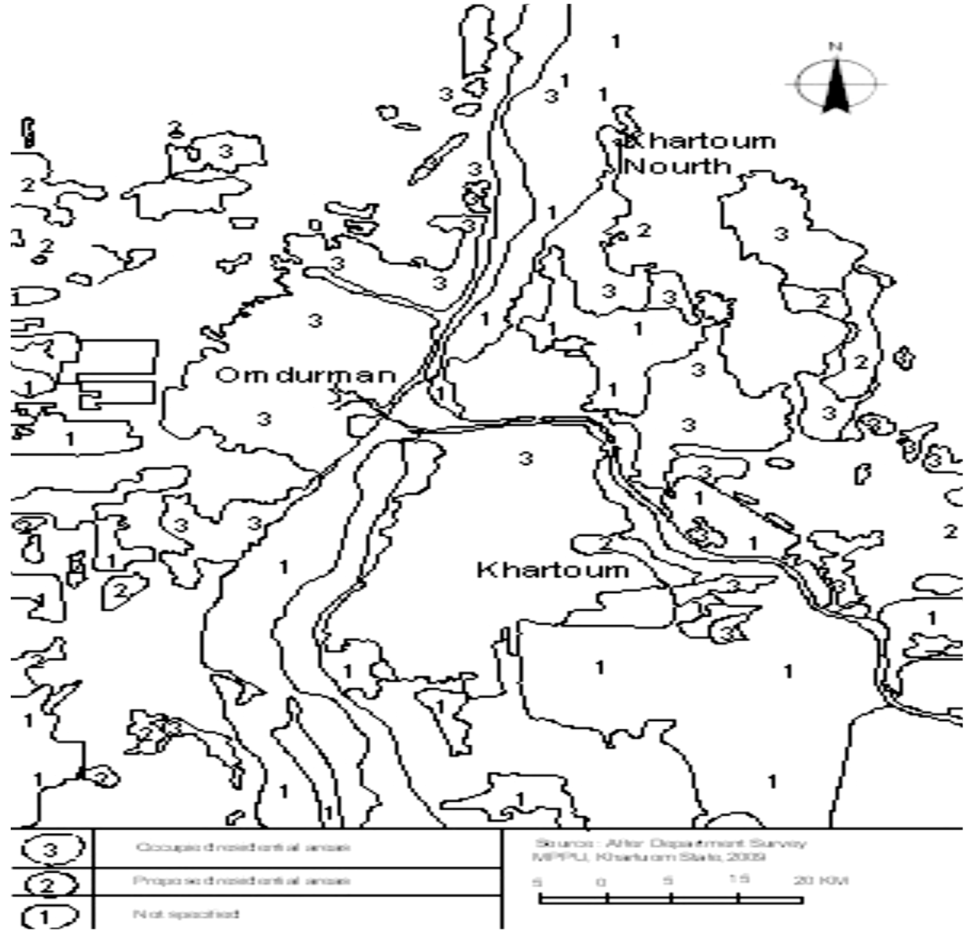
Transportation Network of Greater Khartoum:

Modern Khartoum started with the Turco- Egyptian rule in the nineteenth century, and in early 20th century the Anglo-Egyptian rule re-established it as the capital of the Sudan (Walsh et al 1994). Khartoum startedas a narrow strip limited from the south by the railway station and from the east and north by the Blue Nile and from the west by the White Nile. Old native villages spread to the south of the railway station. Omdurman surrounded by the desert in the west & south, Sabaloqa mountains from the north, and the river Nile from the east, developed as a narrow strip along the River Nile centred on the Imam Mahadi Tomb (Abu Saliem 1970). Khartoum north started on the fringe of the right bank of the Blue Nile on a small strip centred on some Government departments (Gleichen 1905). Old villages distribute along the River Nile and the Blue Nile. Through time Greater Khartoum grew by new residence urban plans and unofficial land sale by native population (Fig.2).

The occupied mass of Greater Khartoum is indicated to by number 1 in figure 2 while the proposed residential areas are represented by number 2. These proposed residential areas appeared to be very small as this might due to the fact that the majority of the ever-proposed urban plans were executed and became part of the urban mass in figure 1, or to the new Government policy to stop further allocation of urban land to individuals. Huge area is given to estate companies such as Sugatra Company as part of the new investment trends into urban land use. These companies in turn sell urban land by retail payment system on longer periods of time with higher pricing. The majority of Khartoum state area in indicated to as not specify by number 3. These non-specified areas according to the fieldwork survey (2009) are miscellaneously used into agricultural, residential and military uses while some of them are occupied by squatter settlements.

Transportation network of Greater Khartoum coincides with its history. Each state has a central bus station from which emerge major transportation axes as illustrated in table (1) & figure (3) in serial numbers. In Greater Khartoum there are 124 transportation routes and 8228 MB (Hafilat) operating over 329 km with a mean road width of 3.5 m. Due to rapid urban growth of Greater Khartoum, first order transportation stations are important as central bus stations (Figure 3). In Khartoum town are Kalakla lafa, Suq Shabi, Suq Markazi and Mina Bari. In Omdurman there are Suq Shabi and Suq Libya. In Khartoum north there are Suq Markazi, and Suq Hilat Kuku. Small focal points developed on these main transportation axes such Mayou, Soba and Jebel Awlia (Figure 3).

Fig 2:Greater Khartuom 2008



In Khartoum there are 38 transportation routes and 2116 MB operating over 4 major transportation axes with total road length of 93 km. Axis (1) goes southward up to Jebel Awlia , and axis (2) goes southeast-ward up to Mayuo. Axis (3) goes eastwardly up to Buri suburb and then turns south to Mujahedien. Axis (4) goes southeastwardly to Soba.

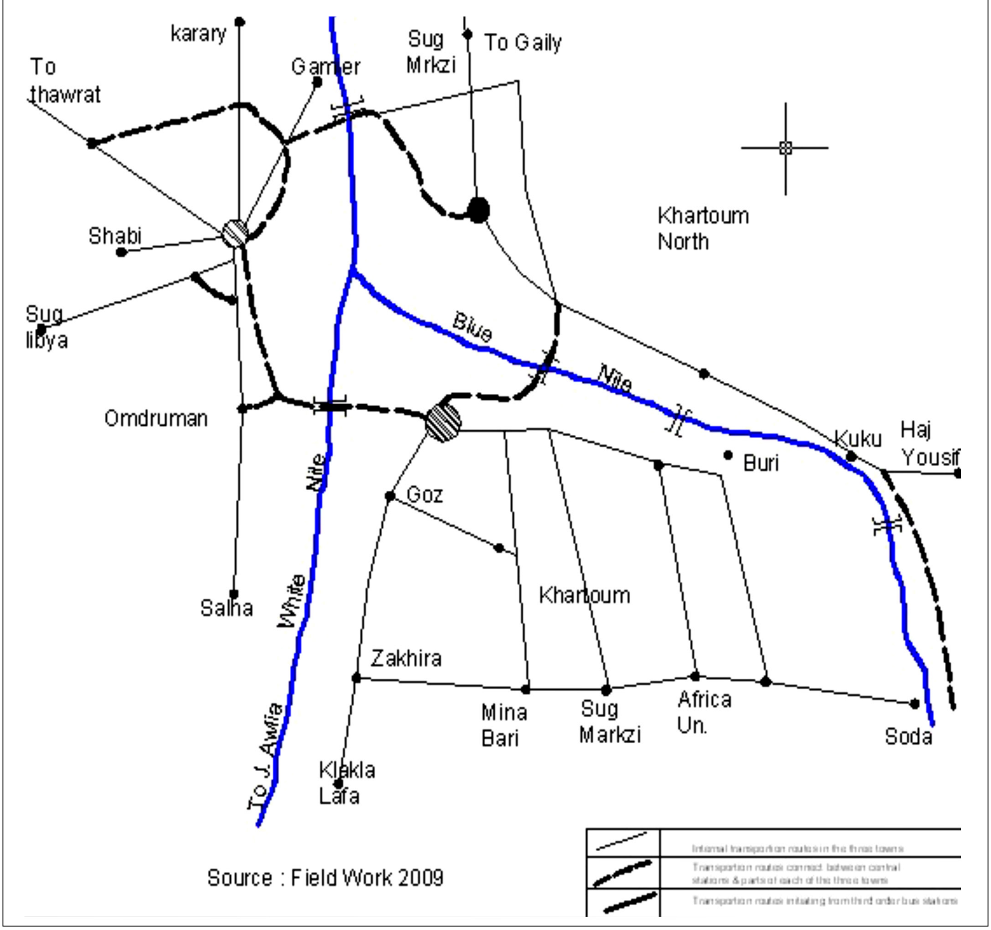
In Omdurman there are 53 transportation routes and 5179 MB operating over 5 major axes with a total length of 134 km. Axis (5) goes westward and southwest–ward up to Um Beddah. Axis (6) goes southward to Muradah, Muhandesien and then el Salha up Gumoia. Axis (7) goes northward to Karary (7), and axis (8) goes northeast to Gamier. Axis (9) goes northwest to el Thwart.

From Khartoum north (Bahri) central station emerges 17 transportation lines with 761 MB operate over 57 km to serve 2 major axes. These axes include axis (10) which goes northwardly to el Gaily and axis (11) which goes northeast to Haj Yousif.

Table (1): Names of transportation axes within Greater Khartoum 's states by number of MB, road width (L), total No. of MB x no. of journeys/ day (No. x 20/12) (Q), and Level of noise pollution in decibels (Leq) by (Josse's model)

States & transportation axes (with serial numbers)	Road width (m)	No. Of MB	Total No. of MB x No. of journeys/ day (No. x 20/12) (Q)	(Leq)
(1) Khartoum City centre to Jebel Awlia (1)	8.0	442	736.6^{1000}	69.4
City centre to Mayuo (2)	8.0	812	1.353.3	73.4
City centre to Buri suburb and Mujahedien (3)	8.0	572	953.3^{1000}	71.2
City centre to Soba (4)	8.0	110	183.3	60.4
Total		2116	3.526.6	79.9dB
(2) Omdurman City centre to Um Beddah (5)	8.0	1780	2.966.6	78.5
City centre up to el Salha & Gumoia (6)	8.0	0925	1.541.6	74.3
City centre to Karary (7)	8.0	0803	1.338.3	73.4
City centre to Gamier area (8)	6.0	0069	115	58.6
City centre to el Thwart (9)	8.0	1602	2.670	77.9
Total		5179	8.631.6	85.5dB
(3) Khartoum north City centre to el Gaily (10)	8.0	562	936.6	71.1
City centre to Haj Yousif (11)	8.0	199	331.6	64.3
Total		761	1.268.3	73.0 dB

Fig 3 :Transportion network of Grater Khartoum



3-2: Geography of noise pollution in Greater Khartoum:

Generally, Mini Buses contribute by 79.5 decibels to position Greater Khartoum in the category of busy traffic of figure (1) to exceed the 45 dB recommended by Word Health Organization as fixed safe noise level for a city. Omdurman comes first (table 1), as busy traffic because of higher number of MB and narrow roads (Alredaisy 2010).

Mean noise level in Khartoum is 79.9 dB. Axis 2 comes first since there is excess of MB over the other axes as it connects with high density residential areas and Mina Barry, which a pivot place for transportation lines with other parts of Sudan. Axis 2 is almost closer to axes 3 and 1, but sharply exceeds axis 4 by 13 dB. In Omdurman the mean of noise level is 85.5 dB. There is a big difference between axes 5 & 8 by range 19.9 dB while the all-other axes have almost closer values. Such a sharp difference is absent in Khartoum north with its general mean of 73.0 dB. The difference between the two major axes of Khartoum north is only range 6.8 dB.

Table 2 provides summary of results for noise levels in Greater Khartoum

Table (2): Summary of results for description of noise levels data in the three states of Greater Khartoum

Statistics	Khartoum	Omdurman	Khartoum north
Mean	68.6	72.5	67.7
Maximum	73.40	78.50	71.10
Minimum	60.40	58.60	64.30
Median	70.3	74.4	67.7
Range	13	19.9	6.8
St. deviation	5.7	8.1	4.8
Relative variability	00.00	0.06	00.00
Coefficient of variation	8.3%	11.1%	7.0%

The two values of the mean and the median had positioned Omdurman first relative to the other two states because it occupies the majority of Greater Khartoum's population.

Measures of distribution in table 2 indicate to differences within the mean and median. The range values are quite big in Khartoum and Omdurman. The values of the standard deviation show a wide discrepancy of the distribution of levels of noise pollution within the mean level in each town. The standard deviation confirms more difference within Omdurman. The big difference between the mean and the standard deviation confirms uneven distribution of noise levels between the transportation axes.

Combining measures of central tendency and dispersion in the variability index will allow considering the dispersion of distribution of noise levels in relation to its average value in Greater Khartoum. In table 2 the values of relative variability and coefficient of variation show steady differences between the three towns. Since these values could help to conclude an uneven distribution of levels of noise pollution in Greater Khartoum, table 3 had run the analyses of variance to test that. Since the calculated value of F- ratio is 1.79 and is less than the critical value of 4.46 at 0.05 significance level, a conclusion is that, there are not any significant differences between the three towns on levels of noise pollution.

Table 3: analysis of variance, at 0.05 significance, level for noise levels data in Greater Khartoum

Khartoum (A)	Omdurman (B)	Khartoum North	Khartoum		Omdurman		Khartoum North	
x	x	x	$^{-}$x- x	x– x)$^{-2}$)	x-x	x -x^{-})^{2})	$^{-}$x -x	x -x^{-})^{2})
69.4	78.5	71.1	0.8	0.64	6	36	3.4	11.56
73.4	74.3	64.3	4.8	23.04	1.8	3.24	-3.4	11.56
71.2	73.4		2.6	6.76	0.9	0.81		
60.4	58.6		-8.2	67.24	-13.9	193.2		
	77.9				5.4	29.16		
274.4	**362.7**	**135.4**		**97.68**		**262.42**		**23.12**
N = 4	N = 5	N = 2	Analysis of variance within groups=47.90 Analysis of variance between groups statistics: Grand mean=69.6, Khartoum x^{-} = , Omdurman x^{-} = 42.05 , Khartoum north: x^{-} = 7.22 Estimate of the analysis of variance between groups=26.63, F -ratio=47.90/ 26.63= 1.79, Significance level = .05 , the critical value = 4.46 1-degrees of freedom for the estimate of the variance between groups = 8 degrees of freedom for the estimate of the vari- 2- ance within groups = 2					
X^{-} =68.6	$^{-}$X 72.5=	X^{-} =67.7						

Intercity transportation connections by central stations:

The three towns are connected together from Khartoum's central stations as in table 4, and from first order transportation stations as in table 5. This connection is served with 4248 MB achieving 6140 journey per day over a mean width of roads of 3.5 meters.

From Khartoum central station emerge 5 axes (numbered 12-16 in table 4 & Fig 3) to serve Omdurman. They hold 2210 MB to connect with the internal transportation network. Transportation route (12) connects the two city centres, while axis (13) goes to southern Omdurman. The transportation route (14) directs to western Omdurman and joins with axis (5) and crosses with axis (6) to boost axis (13). Axes of (15) & (16) meet together in Omdurman central to join axes (7), (8), & (9).

Transportation connections between Khartoum and Khartoum north have 4 axes as numbered 17-20 in table 4 & Figure 3. They add 958 MB to the internal transportation network. Axis (17) connects the two city centres, and axis (19) goes north to crosses with axis (10) in Khartoum north central station. Axis (18) directs east to connect with axis (20) and (11) in Suq Kuku. Axis (20) goes south-eastward of Khartoum north and connects with axis (19) in Suq Kuku. It has two first order transportation stations, one at Suq Kuku and another connects with Gerief-Munshia Bridge.

Khartoum north and Omdurman connect by two transportation routes. The first route (21) links the two central stations. At Shambat Bridge it joins with all axes going to Omdurman. At Azhari roundabout it crosses with axes 8, 15, 16, 24, 25, 34. The second route (22) accompanies route (21) up to Azhari roundabout to cross with all the ever mentioned axes and accompanies axis 16 up to the its last station.

Table (4): Transportation connections between Khartoum central station & Omdurman & Khartoum north

Khartoum central to Omdurman (with serial numbers)	**Road width (m)**	**No. of MB**	**Name of the last station**	**Total No. of MB x no. of journeys/day (No. x 20/12), (Q)**
1-central (12)	8.0	436	Omdurman central station	726
2- southern (13)	6.0	427	Gamoui	710
3- western (14)	8.0	456	Muialih	760
4- northern (15)	8.0	285	Kulia Harbia	475
5- north western (16)	8.0	606	Sabrien	1010
Total	-	**2210**	---	**3581**
Khartoum central to Khartoum north	*Road width (m)*	*No. of MB*	*Name of the last station*	*Total No. of MB x no. of journeys/day (No. x 20/12), (Q)*
1- central (17)	8.0	120	Bahri central station	200
2- eastern (18)	8.0	181	Haj Yousif Wihda	301
3- northern (19)	8.0	465	Kadaro	775
4- south-eastern (20)	8.0	192	Eisailat	320
Total	-	**956**	-	**1596**
Khartoum north central to Omdurman	*Road width (m)*	*No. of MB*	*Name of the last station*	*Total No. of MB x no. of journeys/day (No. x 20/12), (Q)*
1- Omdurman central (21)	8.0	150	Shouhada	250
2- Thawrat (22)	8.0	50	Sabrien	83
Total		**200**		**333**
Grand total		**3208**	-	**4177**

3-4: First order transportation stations and intercity connections:

First order transportation stations serve intercity connections with 1040 MB and 1963 journey per day as in table 5, which equals 25% of total journeys in Greater Khartoum. Many transportation routes connect these stations with central bus stations. Khartoum north central station connects with Suq Shabi Khartoum by 23 MB and crosses at the University of Khartoum underpass with axes 17, 18, 19, and 20. At Suq Shabi it meets axes 2 and those routes coming from Omdurman. Khartoum north central station also connects with Mina Bari by 113 MB and meets with the axis going to Mayou and then by Kalakla lafa to join axis (1).

From Mina Bari emerge two transportation lines reaching Hilal Stadium Omdurman and el Thwart. The transportation route reaching Suq Shabi Omdurman meets with axis (5) and axis (14). It also crosses with axes (6), (7), (8), and (9) at Shouhada station. The route that goes to Thawrat boosts all axes coming from Khartoum central station.

Two transportation lines initiate from Suq Shabi Omdurman to Mina Bari & Suq Markazi Bahri. The first line connects axes (2) and (5) and crosses with axis (1) at Abu hamama. The second line connects with axes (5) and (3) and crosses with axis (11). Suq Shabi Khartoum connects with Suq Libya and crosses with axis (1) at Abu-hamama.

From Mina Bari Khartoum originate 5 routes to connect with first order transportation stations in Omdurman and Khartoum north. Transportation route that connects Mina Bari with Suq Markazi Bahri crosses with axes 17, 18, 19, and 20 at the University of Khartoum underpass. Mina Bari connects directly with Suq Libya. This route crosses with axis (1) at Abu-hamama and meets axis (6) and (5) and before that meets with axes (12), (13), (14), (15) & (16) at Omdurman New Bridge. The two routes directing to Thwart and Hilal stadium have 170 MB and connect with axes (12), (13), (14), (15) and (16) at Omdurman New Bridge to bifurcate after that to northerly and north-westerly routes. Mina Bari connects with Kalakla Lafa and crosses with axis (1) at Zakhera point.Axis (11) has direct transportation linkage with Mina Bari. This axis meets firstly, with axes 17, 18, 19, and 20, at the University of Khartoum underpass. They meet secondly, with axes (11) at Suq Kuku where lines going to Suq Libya from Haj Yousif pass by. This connects axis (11) with axis 5. Also, Kalakla lafa connects directly with Suq Libyaand by that connects with axes11 and 5.

Table (5): Spatial connections of First order transportation stations In Greater Khartoum following transportation ordering initiating from a city centre

Name of transportation line with serial number(Origin – Destination)	No. of MB	Road width	Total No. of vehicles x no. of journeys/ day (No. x 20/12) (Q)
Shabi Omdurman-Mina Bari (23)	210	8.0	350
Shabi Omdurman-Suq markzi Bahri (24)	100	8.0	166
Shabi Omdurman- Bahri (25)	41	8.0	68
Shabi Khartoum -Suq Libya (26)	67	8.0	111
Shabi Khartoum - Bahri (27)	23	8.0	38
Mina Bari-Suq Markazi Bahri (28)	100	8.0	166
Mina Bari-Suq Libya (29)	25	8.0	41
Mina Bari-Thawrat (30)	38	8.0	63
Mina Bari-Hilal Stadium (31)	132	8.0	220
Mina Bari- Kalakla lafa (32)	200	7.0	333
Mina Bari-Haj Yousif (33)	70	7.0	116
Haj Yousif-Suq Libya (34)	150	8.0	250
Kalakla lafa- Suq Libya (35)	25	8.0	41
Grand total	1040	-	1963

3-5: The impact of intercity transportation connections on noise pollution:

Intercity transportation connections in Greater Khartoum and levels of noise pollution are illustrated in Table (6, a, b, c) which is based on tables 4 & 5. Such connections have led to the appearance of new transportation lines, and changing ever existing noise levels. Intercity transportation connection between Khartoum and Omdurman as in table 6, a, led to the appearance of

Khartoum central station-Ingaz Bridge (Omdurman New Bridge) transportation line that gives 81.29 dB. It also changed levels of noise pollution on axis 1 by adding 70.24 dB to the portion between Khartoum central station and Goz crossing, and 65.08 dB to the portion between Goz crossing and Kalakla Lafa. These additions exceed the ever-existing noise levels to give a general noise level of 74.4 dB with a difference of 5 dB for the first portion, and 72.2 dB with a difference of 2.8 dB for the second portion.

Transportation connections between Khartoum & Omdurman led to the appearance of Goz Crossing - Suq Shabi Khartoum line that gives 69.9 dB. Because some transportation lines reach firstly Suq Shabi Khartoum and then Mina Bari, they add 64.15 dB to the ever existing 73.4 dB on that axis with a general level of noise of 74.8 dB to give a difference by 1.4 dB.

Intercity transportation connections between Khartoum & Khartoum north influenced axis 2 between Khartoum central station and Khartoum Hospital by 69.9 dB to change the noise level to 79.2 dB instead of 77.41 dB. Because axis 3 meets at University of Khartoum underpass with transportation routes going to Khartoum north, it accepted 75.3 dB to raise the ever-existing level from71.2 dB to 77.9 dB with more 6.7 dB. Axis 4 accepts 63.25 dB due to transportation connection between Mina Bari & Suq Markazi Bahri, and Mina Bari-Haj Yousif to change the general level to 66.5 dB instead of 60.4 dB.

Intercity transportation connections between Omdurman, Khartoum &Khartoum north*(table 6, b*) have led the appearance of Ingaz bridge - Omdurman locality line with 77.42 dB, and the Ingaz bridge- Muhandiesin Crossing line with 76.04 dB. They also influenced axis 5 with 72.4 dB to become 80.7 dB, and axis 7 with 66.6 dB to become 75.3 dB, while affected axis 8 with 62.4 dB to become 68.0 dB, and axis 9 by 72.4 dB to become 80.2 dB. Because Azhari crossing is a focal point for all transportation routes connecting Omdurman with Khartoum north and Khartoum towns it recorded 77.94 dB.

Table (6, a): Levels of noise pollution (in dB) in Khartoum state due to transportational connections with Omdurman &Khartoum north states

States **(1) Khartoum town**	Lines by serial numbers	No of MB	Additions of noise In dB	Ever noise level	Total No. of MB	New Noise level	difference
Khartoum central-Ingaz bridge	12,13,14,15,16,23 ,26,29,30,31,35	2709	81.29	-	-	-	-
Axis 1 –a: Khartoum central-Goz crossing	23,26,29,30,31,35	497	70.24	69.4	939	74.4	5.0
Axis 1-b: Goz crossing -Kalakla Lafa	35,32	225	65.08	69.4	667	72.2	2.8
Axis 1 –c: Goz crossing -Suq Shabi Khartoum	23,26,29,30,31	472	69.9	-	-	-	-
Axis 2- a: Khartoum central-Khartoum Hospital	18,20,28,	473	69.9	77.41	1967	79.2	1.8
Axis 2 –b: Suq Shabi Khartoum - Mina Bari	29,30,31	195	64.15	73.4	1007	74.8	1.4
Axis 3 - Khartoum Hospital-University of Khartoum underpass	17,18,19,20,27,28	1079	75.3	71.2	1615	77.9	6.7
Axis 4	28,33	170	63.25	60.4	280	66.5	6.1

In Khartoum north, intercity transportation connections with Khartoum & Omdurman towns (table 6, c) influenced axis 10 by 69.81 dB as connects with axis (19). This changed the ever- existing level from 71.1 dB to 74.9 dB, to give a general level of 74.9 dB. In addition, crossing of axis 10 at Mouasasa with transportation routes going to Omdurman had added 77.11 dB to the ever-existing noise level of 71.1 dB to increase the general level to 79.3 dB.

Concerning axis (11) many additions of noise levels are detected up to its last destination: -

(1) Firstly, 72.33 dB were added when connects with routes coming from Khartoum at the Blue Nile Bridge, to change the ever-existing noise level from 64.3 dB to a 73,9 dB

(2) Secondly, it accepts71.39 dB on its way to Hilat Kuku when it joins routes coming from Khartoum state at Military Forces Bridge. This addition changed noise level from 64.3 dB to a general noise level of 73.3 dB.

(3) Thirdly, between Hilat Kuku and its last destination at Suq Wihda, this axis meets with routes going to Mina Bari and Suq Libya to accept 65.22 dB, to change the general level to 69.3 dB instead of 64.3 dB.

Table (6, b): Levels of noise pollution (in dB) in Omdurman town due to transportational connections with Khartoum &Khartoum north towns

Omdurman town	Lines by serial numbers	No of MB	Additions of noiseIn dB	Pre-noise level	Total No. of MB	New Noise level	difference
A:Ingaz bridge-Omdurman locality	12,15,16,30,31	1497	77.42	-	-	-	-
B:Ingaz bridge-Muhandiesin crossing (axis 6)	13,14,23,26,29,35	1210	76.04	-	-	-	-
C:Muhandiesin crossing-Omdurman central	14,13,23,26,29,35	1210	76.04	74.3	2135	79.7	5.4
Axis 5	13,26,29,34,35	694	72.4	78.5	2474	80.7	2.2
Axis 7	15	285	66.6	73.4	1088	75.3	1.9
Axis 8	21	285	62.4	58.6	354	68.0	9.4
Axis 9	16,22,30	694	72.4	77.9	2296	80.2	2.3
Azhari crossing	21,22,24,25,30, 31,8,21,15,16	1621	77.94	-	-		

Table (6, c): Levels of noise pollution (in dB) in Khartoum north state as due to transportational connections with Khartoum & Omdurman towns

Khartoum north state (Bahri)	Lines by serial numbers	No of MB	Additions of noise In dB	Ever noise level	Total No. of MB	New Noise level	difference
Axis 10	19	465	69.81	71.1	1027	74.9	3.8
Axis 10: Mouasasa crossing	10,19,21, 24,34	1427	77.11	71.1	1989	79.3	8.2
Axis 11-a: Bahri central- Blue Nile Bridge crossing	17,19,28	685	72.33	64.3	884	73.9	9.6
Axis 11-b: Blue Nile Bridge crossing - Kober	11	199	-	64.3	199	-	-
Axis 11-c: Kober-Hilat Kuku	18,20,33,34	593	71.39	64.3	792	73.3	9.0
Axis 11-d: Hilat Kuku-Suq Wihda	33,34	230	65.22	64.3	429	69.3	5.0

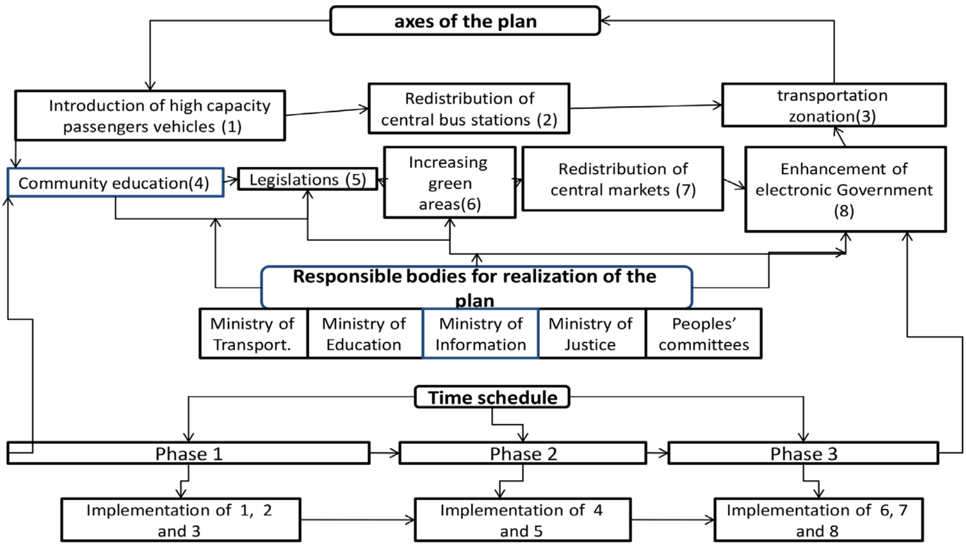
Greater Khartoum exceeded the 45 dB proposed by Word Health Organization as the safe noise level for a city, due to many factors among which is the increasing intercity transportation connections. Generally, additional vehicles are mismatched by road improvement. The effect of road width on increasing level of noise pollution is evident within urban Khartoum town (Alredaisy 2010). New bridges on the Niles will increase future connections because of recent distribution of economic activities within Greater Khartoum. Population growth increased demand for public transportation as expected elsewhere. In urban areas of the world 3.3 billion lives and over the next three decades Africa's urban population will double from 294 billion to 742 billion (UNFPA, 2008). Population rate of increase In Greater Khartoum was 4.92 in 1956, increased to 7.76 in 1973, and to 8.75 in 1983 to reach 13.7 in 1993. It also had accepted internal migration of Sudan by 39% in 1983 and 45% in 1993 (MFEP 1956 – 1993). Since Greater Khartoum is drawing resources from other regions of Sudan, it is expected that urban growth will accelerate.

The noise level of 79.5 decibels in Greater Khartoum is somehow equals many urban centers worldwide where 19 countries that had submitted road transport data to the European Environment Agency (EEA), depicted an average of 55 decibels or higher than the 45 dB recommended by World Health Organization as safe noise level (WHO, 1997). There are wide discrepancies on noise levels worldwide. Metropolitan areas in India usually register an average of more than 90 dB. Mumbai is rated the third noisiest city in the world (India Together 2009). Tarulescu (2007) studied traffic noise pollution in Brasov, in Romania, and found that in some of the studied intersections, the medium level of noise pollution (Leq) is frequently over 70 dB, and for the year 2020 they forecasted a duplication of this value. The average level of Leq of all urban zones in Belo (BH) city in Brazil was 69.5 dB, and that the noise of motor vehicles is what contributes more to noise pollution (Alvares et al, "Date not specified"). The study of environmental noise pollution in city of Curitibi, Brazil, found that 93.3% out of the locations display, during the day, extremely high values of equivalent sound level over 65 dB, and 40.3% out of the locations measured display during the day extremely high values of equivalent sound levels over 75dB (Henrique et al 2003). The study of environmental noise pollution in city of Curitibi, Brazil, found that 93.3% out of the locations display, during the day, extremely high values of equivalent sound level over 65 dB, and 40.3% out of the locations measured display during the day extremely high values of equivalent sound levels over 75dB (Henrique, 2003).Noise intensity levels at various locations in Karachi show the highest record at peak time as 88.89 dB and the lowest record as 63.65 dB (Mehdi" Date not specified"), while in Lahore recorded 110 dB (WHO,1997). However, 20% of the European Union's population suffered from noise levels which may be hazardous due to annoyance, sleep disturbance and cardiovascular changes (WHO,1997).In London noise pollution recorded 78.5 dB and in Newcastle upon Tyne it recorded 80.4 dB (Widex Noise Report 2008), while it recorded 88 dB in Cairo recorded 88. dB and 74 dB in Amman (WHO, 1997).

Conclusions:

Problem of noise pollution in Greater Khartoum state is a facet of its growth and development since huge number of urban populations lives there to be served by public transportation vehicles. Spatial variations are quite evident on levels of noise pollution. Central bus stations and main transportation axes have higher levels of noise pollution as being related to excess Mini Buses, number of journeys and road width. The increasing rate of modernization and trends for private car ownership will demarcate the future of increasing noise pollution in Greater Khartoum. To curb the impacts of noise levels in Greater Khartoum a concise clear plan can be proposed. The plan is outlined in figure 4 with its main axes, the responsible bodies for its realization and its time schedule.

Figure (4): Plan for curbing noise pollution impacts in Greater Khartoum



The main axes of the plan included the introduction of higher capacity passengers' transportation vehicles with low noise engines; redistribution of central bus stations; transportation zonation; community education; legislation on permitted limits of noise levels; increasing green areas; redistribution of central markets and enhancement of the electronic Government (fig.4). The responsible bodies of the realization of this plan include Ministries of Transportation; Education, Information and Justice as well as the Peoples' committees at the community level. The time schedule included three phases for gradual successive implementations of the proposed axes in order to curb noise pollution in Greater Khartoum.

Introduction of higher capacity passengers' transportation vehicles with low noise engines instead of the low passengers' capacity ones will reduce noise levels by nearly 1/3, since there will be replacement by 1 for 3 per vehicle, regardless of engine type. Redistribution of central bus stations and transportation zonation will divide the state into sectors and this will evenly redistribute transportation vehicles. However, widening of roads and solving problems of traffic congestion are integral parts to these three axes. Community education will inform people about transportation network and health hazards of noise pollution. Governmental legislations on permitted noise levels will protect related regulations on organizing transportation. Increasing green areas will reduce noise pollution as confirmed worldwide. Redistribution of central markets within the state will create new focal points that cut down population movements towards the city Centre. This can be further enhanced by the introduction of electronic Government which will provide services from remote.

Realization of this proposed plan depends on collective work of the entitled Ministries in figure 4. Operation, modernization and organization of transportation network and vehicles is the responsibility of Ministry of Transport. But this cannot work without education and media. Schools, TV, Radio and Newspapers can transfer information and knowledge about transportation network, traffic legislations and hazards of noise pollution. Ministry of Justice protects legislations on the permitted noise levels and executes penalties. Duties of Peoples' committees should focus on transferring information to local communities about transportation and noise health hazards by enhancing youth clubs, religious men and women. Implementation of this plan can be stepped wisely. In the first phase it is necessary to provide the infrastructure for noise levels curbing by the introduction of higher capacity passengers' transportation vehicles with low noise engines, redistribution of central bus stations and zonation of Khartoum state. Secondly, is community awareness about transportation, noise pollution and legislations. Thirdly, is the increasing of green areas, redistribution of central markets within Greater Khartoum and enhancement of electronic Government.

By that way it is expected to reduce noise levels in Greater Khartoum but, increasing GNP of the country by introduction of petroleum into the export list of the country, increasing per capita share of national income and cease of war in southern and western Sudan would certainly hold more hopeful and promising future for the country as a whole within which the controlling of noise and gas pollution in Greater Khartoum is possible.

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6

Predicting the Contribution of Mini Buses in the Geography of Environmental Noise Pollution in Urban Khartoum town

6

Predicting the Contribution of Mini Buses in the Geography of Environmental Noise Pollution in Urban Khartoum town

Sound can be described as a tiny variation in air pressure, detected by some receiver. Typical sound pressure amplitudes range from a few micropascals to a few hundred Pascals that fluctuate around atmospheric pressure (~101,000 Pascals). This variation in air pressure travels as a longitudinal wave, i.e., a compression wave, which propagates throughout the medium (air) at a velocity called the sound speed. In air at 20 °C, the speed of sound is about 344 m/s. In general, the tiny variation of pressure oscillates very rapidly in time around the atmospheric pressure. In the audio-range, these oscillations occur between 20 and 20,000 times per second. In other words, audible sound is made up of frequencies between 20 and 20,000 Hz (frequency). Very low tone corresponds with 20 Hz, while 20,000 Hz corresponds to a very high tone. Most noises are composed of many different frequencies. The traffic noise of motor vehicles is the most important type of noise to which people are exposed in their everyday life.

Noise pollution is defined as a displeasing human-, animal- or machine-created sound that disturbs the activity of human or animal life (Wikipedia 2009). World Health Organization has fixed 45 dB as the safe noise level for a city. According to W.H.O. which considers noise pollution to be the world's third worst after polluted air and water, exposure for more than eighty hours a day to sound in excess of 85 dB is potentially hazardous (IOL, 2009). Cvetković1, et al (1997) produced the typical examples of levels of noise pollution as illustrated by Figure (1).

Figure (1) depicts range of noise from 0 to 140 decibels. Divisions of noise levels correspond with sub ranges of noise levels and included quiet countryside; living room; conversation; busy traffic; pneumatic; threshold of discomfort and threshold of pain levels. Each level of noise pollution has a range upon which a noise level is decided for whatever a geographic location.

Starting from 0- 20 decibels is quiet countryside. From 20- 40 decibels is living room, 40-60 decibels is conversation, 60-80 decibels is busy traffic. 80-100 decibels is pneumatic, 100-120 decibels is threshold of discomfort and from 129-140 decibels is threshold of pain. Difference between each level is 40 decibels interval. The decibels value in the middle of each level is the mid value between each two noise levels depicted by figure (1) where for example the value of 130 decibels is the mid noise level between threshold of discomfort and threshold of pain and so on.

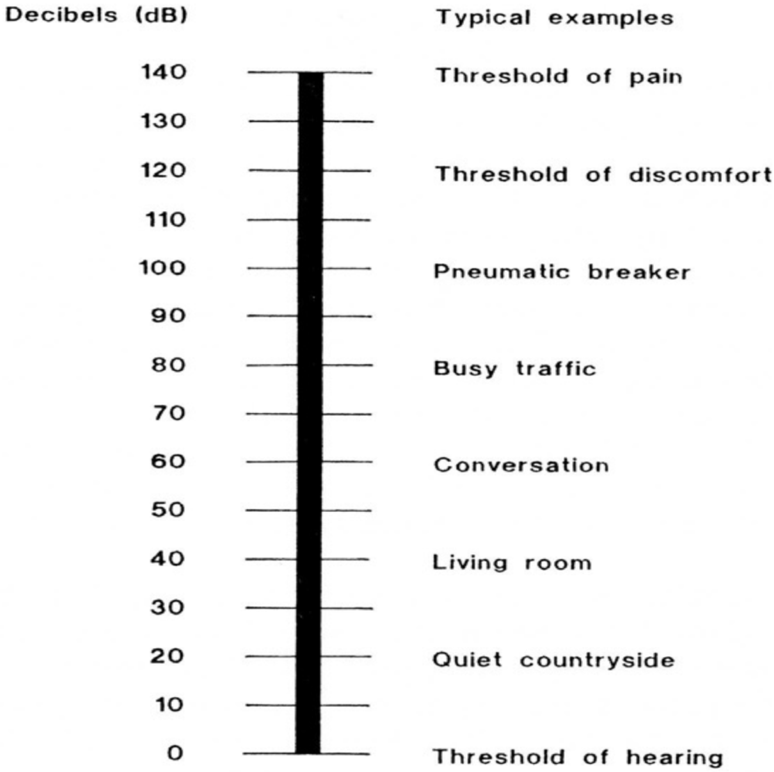


Fig. 1: Typical examples of levels of noise pollution

Source: D. Cvetković1, et al (1997)

There are numerous models for the prediction of the contribution of public transportation vehicles in the total receipt of noise pollution in urban areas. These mathematical models are used to determine equivalent noise level (Leq) as the most representative physical variable quantifying noise emissions. The equivalent noise level corresponds to the sound pressure of a fictions stationary noise source emitting the same acoustic (audio) energy as the actual non-stationary (static) source. The equivalent continuous noise level in A-weighted decibels (dBA) is widely recognized as a stable descriptor of motor vehicle noise levels (Traulescu, S. et al. 2007). It is recommended by many national and international regulatory agencies as a suitable index for use in motor vehicle noise assessments. Leq is known to correlate well with known effects of the noise environment on the individual and the public. The physical parameters to which Leq is correlated are, among others, traffic intensity, type of road surface, type of urban area, height of buildings, width of road, etc.

Mathematical models for prediction of traffic noise usually extract the functional relationship between the parameter of noise emission, Leq, and measurable parameters of traffic and roads. The classical functional relationships have based on data measured through semi-empirical models, typically regression analysis. Of all the mathematical models available in literature, the ones which present this feature are those proposed by Burgess (1977), Josse (1972), and Fagoti. These functional relationships are essentially based on statistical analysis (i.e. regression techniques) and they are: -

$L_{eq} = 55.5 + 10.2 \log Q + 0.3p - 19.3 \log (L / 2)$ (Burgess)

$L_{eq} = 38.8 + 15 \log Q - 10 \log L$ (Josse)

$L_{eq} = 10 \log (N_c + N_m + 8N_{hv} + 88N_b) + 33.5$ (Fagoti)

Here p is the percentage of heavy vehicles, L is the road width, Q is the total number of vehicles per hour, Nc is the number of light vehicles per hour, Nm is the number of motorcycles per hour, Nhv is the number of heavy vehicles per hour, Nb is the number of Buses per hour. The total number of vehicles per hour, Q, is expressed as the equivalent number of cars and obtained, as before, under hypothesis that one heavy vehicle is equivalent to 6 light vehicles and one motorcycle to 3 light vehicles. Although these correlations are nonlinear, they do not provide very accurate approximation of the trend followed by sound pressure level according to a certain number of physical parameters because any models itself includes the flow and composition of the road traffic which may be different than examined in urban areas.

Data on number of Mini Buses and transportation lines, confined to the year 2009, is collected from Department of Public Transportation & Petroleum of Khartoum town. This data concerns with Mini Buses with passengers' capacity of 15-25 persons. This is because Mini Buses are the main public transportation vehicles in urban Khartoum town, except few Taxi cars, and they are working for long hours per day. Determination of the main transportation axes is done by fieldwork during June 2009. Khartoum town is divided into four main transportation axes emerging from Khartoum central bus station to the end points in Jebel Awlia; Mayou, Mujahedien and Soba. Road width is estimated by travelling on the transportation network. Mean of number of journeys per day per vehicle is estimated as 20 journeys in a round trip journey on a mean time of 12 working hours per day as based on observation and interviewing with some Mini Buses drivers.

Because there is lack of data necessary to apply most of the models outlined in section 1 in the developing world, since they are mainly designated for the developed world where the data feeding them is so sophisticated and hence the results are highly reliable, this paper used the mathematical model for noise level prediction proposed by Josse which does not requires much data as the other models indicated earlier. This model states that:

$$Leq = 38.8 + 15 \log Q - 10 \log L$$

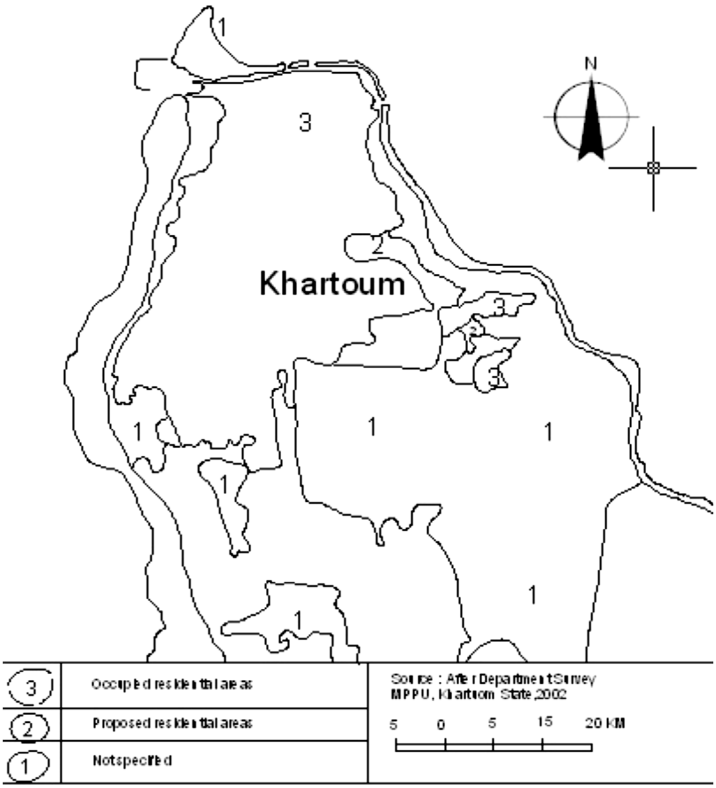
Where Q is the total number of vehicles per hour, L is the road width.

Statistical methods used for the analysis of data included the range, mean, coefficient of variation and the standard deviation as well as multiple correlation and analysis of variance to depict general situation and the statistically significant differences on noise levels in urban Khartoum town.

Transportation Network of urban Khartoum Town:

Modern Khartoum town started with the Turku- Egyptian rule in the nineteenth century and in early 20th century the Anglo-Egyptian rule re-established it as the capital of the Sudan (Walsh et al 1994). It started as a narrow strip limited from the south by the railway station and from the east and north by the Blue Nile, while the White Nile limited its western boundary. To the south of the railway station native villages distribute along the two Niles and in the clayey plain in between. Through time Khartoum town grew by new residence urban plans, and unofficial land sale by native population which marked the distribution of squatter areas in this town (Fig.2).

Fig 2:Khartuom Town in 2008



The occupied mass of urban Khartoum town is indicated to by number 1 in figure 2 while the proposed residential areas are represented by number 2. These proposed residential areas appeared to be very small as this might due to the fact that the majority of the ever-proposed urban plans were executed and became part of the urban mass in figure 1, or to the new Government policy to stop further allocation of urban land to individuals. Huge area is given to estate companies such as Sugatra company as part of the new investment trends into urban land use. These companies in turn sell urban land by retail payment system on longer periods of time with higher pricing. The majority of urban Khartoum town area in indicated to as not specified by number 3. These non-specified areas according to the fieldwork survey (2009) are miscellaneously used into agricultural, residential and military uses while some of these areas are occupied by squatter settlements.

Transportation network of Khartoum town (fig.3) coincides with its history of urban growth. It consists of the main central station, ''Jackson's Yard'', near Khartoum Stadium, and the main transportation axes emerging from there to various parts of the town. Generally, four main transportation axes could be identified here. Axis, one goes along a southward direction up to Jebel Awlia; and axis two goes southeast-ward up to Mayou area. Axis three goes east and then south up to Mujahedeen, while the fourth axis goes to southeast of Khartoum town up to Soba area. Within this network structure we can distinguish nodes, edges (arcs), end nodes, branches and circuits (table 1) below.

Rank	Point of departure and destination	Axis, Nodes and End nodes	Axis number	No. of Mini Buses	Road Width ''One carriage'' (L)	Total Number of Mini Buses x number of journeys/ day (No. x 20/12) (Q)	(Leq) equivalent noise level
1	Khartoum central station	node	-	2116	4	3526	86.0
2	Khartoum central station- University of Khartoum + University of Khartoum node	Axis ,node	3	1776	3	2960	86.08
3	Mina Bari	node	2	1754	4	2923	84.7
4	Suq Shabi Khartoum	node	2	1619	4	2968	84.85
5	University of Khartoum node	node	3	1530	2	2550	83.81

6	Khartoum central station-Suq Shabi Khartoum	axis	2	1384	4	2306	83.2
7	military forces bridge node	node	3	1077	3	1795	82.84
8	University of Khartoum - military forces bridge	axis	3	945	4	1575	80.65
9	Khartoum central station-Goz + Goz node	Axis, node	1	891	4	1485	80.37
10	Suq ShabiK Khartoum-Mina Bari	axis	2	812	4	1353	79.76
11	Zakhira point +Zakhira node-Kalakla Lafa	Node, axis	1	532	4	886	77.01
12	Omdurman – Mina Bari node	axis	1,2	505	4	841	76.6
13	Omdurman Suq Shabi-Goz and -Goz Suq Shabi and Mina Bari Khartoum	Axis, node	1,2	449	4	748	75.90
14	Goz-Shagara	axis	1	410	3	683	76.54
15	Kalakla Lafa node	node	1	406	3	676	75.24
16	Kalakla Lafa- jebel Awlia	axis	1	392	3	653	76.25
17	military forces bridge-Khartoum north areas	axis	3	373	4	621	74.69
18	international University of Africa node	node	4	358	4	596	74.42

19	Suq Markazi-international University of Africa	axis	4	298	3	496	74.46
20	Suq Markazi node	node	4	259	4	431	72.31
21	Khartoum north central station-Suq Markazi Khartoum	axis	4	193	4	321	70.39
22	Jebel Awlia end node	End node	1	185	3	308	71.35
23	Khartoum central station-Suq Markazi Khartoum	axis	4	179	4	298	69.91
24	Mina Bari-Mayou	axis	2	160	3	266	70.40
25	military forces bridge- I nternational University of Africa point + Buri-Mujahedien	axes	3	132	4	220	69.16
26	Mayou node	node	2	130	3	216	69.04
27	Suq Markazi Khartoum-Soba +international University of Africa point-Soba +Soba	Axis, end node	4	122	3	203	68.64
28	Khartoum central station-Soba	axis	4	110	3	182	67.93
29	military forces bridge-Buri +Buri node	Axis ,node	3	94	3	156	66.92

30	Khartoum north central station-Suq Shabi Khartoum	Axis	4,2	83	4	138	64.75
31	Haj Yousif-Mina Bari	Axis	3,2	70	4	116	63.73
32	Haj Yousif-Mayou	Axis	3,4	60	3	100	64.03
33	Mina Bari-Mayou	Axis	2	40	3	66	60.70
34	Mayou-Kalakla Lafa	axis	2,1	30	3	50	59.51
Total		-	-	19474	x-=3.5	32456	x-= 72.15

Source: Fieldwork, 2009

The operation of public transportation vehicles within this network is stepwise movement. At every axis some sub-stations are located that create focal points for public transportation vehicles, and at the same time initiate new transportation routes to their neighborhoods. These major focal points include the Mina Bari, Suq Markazi, Suq Shabi and Kalakla Lafa. However, new small focal points developed on these main transportation axes due to recent expansion of public transportation network, such as Mayou, Soba and Jebel Awlia sub-stations (Fig.3). In addition, Khartoum town connects with Omdurman and Khartoum north towns through six bridges and these interconnections increase road load of public transportation vehicles within Khartoum town. These bridges are intense concentration points of public transportation vehicles, and similarly the sub-stations earlier indicated. In our context here, this network is served with 19474 Mini Buses running 32456 journeys per day on roads with average width of 3.5 meters (table 1).

Table (1) ranks Mini Buses according to their numbers versus a type of component of the transportation network, where such components are distinguished as, axes, nodes, or end nodes. The width and operation through daily journeys per a Mini bus are also calculated.

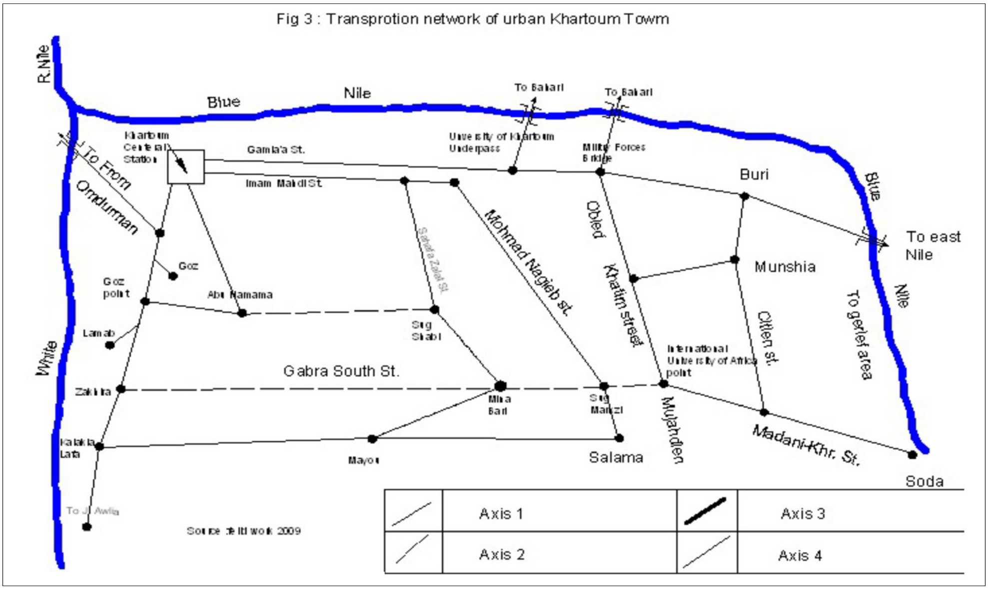


Table (1): Points of departure and dest

Levels of noise pollution in Khartoum town:

Levels of noise pollution caused by Mini Buses within Khartoum town are illustrated as (Leq) by the last column of table 1. Table 2 grouped these noise levels to show their statistical characteristics. The general contribution of Mini Buses by the mean value of (x^{-} = 72.15 decibels) and the Median (75 decibels) had put Khartoum town towards bust traffic level of figure 1. The percentage calculation gives 67.6% to the range of 70-89 decibels, and 32.4% to the range of 55-69 decibels.

Measures of distribution in table 2 indicate to the range value of 86.08 to 58.5 decibels to position Khartoum town between pneumatic breaker and conversation levels of figure1. The spread of individual values within this range in relation to the average (mean) is shown by the cumulative percentage frequency in table 2. For every class of noise level of pollution in Khartoum town there is an indicator for the proportion of noise values lying below the upper limit of that class. Here, for the class of 85-89 decibels we find that 100% of noise pollution is lying below 89 decibels, where records of table 1 confirm the absence of that record. Other classes get the values of 94.2% below 84 db, 73.6% below 79 db, 53% below 74 db, &32.4% below 69 db, 14.7% below 64 db & 2.9% below 59 db respectively.

Table (2) Grouped levels of noise pollution in urban Khartoum town

Grouped Levels of noise pollution (dB)	Freq.	% freq.	Cumu. % freq.	Axes number & frequency % of occurrence of a noise level								
				1	%	2	%	3	%	4	%	Total percent
55-59	1	02.9	02.9	1	2.5	2	5.0	-	-	-	-	7.5
60-64	4	11.8	14.7	-	-	3	7.5	2	5.0	2	5.0	17.5
65-69	6	17.7	32.4	-	-	2	5.0	2	5.0	4	10.0	20.0
70-74	7	20.6	53.0	1	2.5	1	2.5	1	2.5	4	10.0	17.5
75-79	7	20.6	73.6	4	10.0	3	7.5	-	-	-	-	17.5
80-84	7	20.6	94.2	1	2.5	3	7.5	3	7.5	-	-	17.5
85-89	2	05.8	100	-	-	-	-	1	2.5	--	-	2.5
total	34	Total percent		7	17.5	14	35.0	9	22.5	10	25	100

General statistics	Multiple correlation statistics
Mean =73.5 dB, Mole =72.69 dB Median = 75 dB Range=86.08-59.51 dB Mean deviation = 1.02 Standard deviation = 5.80 Relative variability = 1.38 % Coefficient of variation = 7.89%	Variables used: $X_{1,}$ denotes level of noise ''Leq" in dB, X_2 denotes Q, X_3 denotes "L" as explained in table (1). Constants: a= 0.15, b =0.23, c =0.21 squared standard error =9.005 variance =5.18 r_2= 0.48 coefficient of multiple correlation= 0.69

The value of the Mean deviation which is 1.02 and the value of the standard deviation which is 5.80 indicate to a wide discrepancy of the distribution of the level of noise pollution within the mean level in Khartoum town. The big difference between the values of the mean and the standard deviation indicates to uneven distribution of levels of noise pollution.

Combining measures of central tendency and dispersion in the variability index allows the dispersion of distribution of noise levels to be considered in relation to the average value of the noise level about which it has been measured. This is confirmed by the value of relative variability which equals 1.38 % and the coefficient of variation that equals 7.89%. The value of the variance of 5.18 puts a general conclusion that, there is an uneven distribution of levels of noise pollution within Khartoum town.

Road width and number of journeys per Mini Buses partially determine levels of noise pollution in urban Khartoum town where the value of the correlation coefficient (r_2= 0.48) attributes 48% of noise pollution to these two factors. The coefficient of multiple correlation of 0.69 indicates to a somewhat positive strong correlation between noise pollution levels and these two factors. Roads of Khartoum town are mostly narrow, and are overloaded by annual additions of vehicles, particularly in the city center. Here, the inlets and the outlets to/from the main central stations are quite few, and traffic congestion is evident. Even the main axes, discussed her, are narrow within the city centre. Some of them were widened recently, while others were converted to highways.

Local Government Authority does not provide public transportation services. The private sector does that role, where the factors of high cost of operation had forced this sector to increase working hours per day and to introduce Mini Buses (locally called Hafilat) of 15 to 25 persons instead of max Buses of high capacity of 50 to 60 passengers.

The general geography of levels of noise pollution shows noticeable distribution within the four axes indicated in table 2. Starting from the lowest to the highest, the level of noise pollution between 55 – 59 dB restricts only, with an equal share, to axes 1 and 2. The second level of 60 – 64 dB has more excess on axes 2, and is also seen on axes 3 and 4. The third level of 65 – 69 dB weights more on axis 4 and had an equal share between axes 2 and 3. The fourth level of 70 -74 dB illustrates an even distribution between axes 1, 2 and 3 with more excess in axis 4. However, the fifth level of 75 – 79 dB is confined to axes 1 and 2 with somewhat small difference between them. The sixth level of 80 – 84 has equal distribution on axes 2 and 3 and small occurrence on axis 1. The highest level of 85 – 89 dB restricts only to axis 3. Differences exist within these axes between nodes, edges (arcs), and end nodes, branches and circuits (Fig.3 & table 1). The general conclusion is that axis 2 has strong presence at all levels of noise pollution, and particularly the highest levels of 75-84 dB, and similarly axis 1. Differences between these axes were treated statistically by the analysis of variance (table 3).

Table 3: Analysis of variance of levels of noise pollution on the main axes of transportation network of urban Khartoum town

Axis 1	Axis 2	Axis 3	Axis 4	Axis 1 $(x-x^{-})^2$	Axis 2 $(x-x^{-})^2$	Axis 3 $(x-x^{-})^2$	Axis 4 $(x-x^{-})^2$
2116	2116	2116	2116	2,416,159	1,993,744	168662169	3020.6
891	1754	1776	358	89,640.4	1,102.500	919105.69	392.04
532	1619	1530	298	3,552.16	837225	507941.29	6368.04
505	1384	1077	259	7,499.56	462400	67444.09	14113.44
449	812	945	193	20,344.76	11664	16307.29	34151.04
410	505	373	179	32,978.56	39601	197402.49	65433.64
406	449	132	122	34,447.36	65025	469636.09	71716.84
392	160	94	110	39,840.16	295936	523162.89	86907.04
185	130	70	83	165,323.6	329476	558457.29	100966.84
30	83	60	60	315,394.6	385641	573503.29	25217.44
-	70	-	-	-	401956	-	-
-	40	-	-	-	440896	-	-
-	30	-	-	-	454276	-	-
∑x=5916 N=10 x^{-} =591.6	∑x=9152 N=13 x^{-}= 704	∑x=8173 N=10 x^{-} =817.3	∑x=3778 N=10 x^{-}=377.8	$\sum(x-x^{-})^2$ = 43,730,43	$\sum(x-x^{-})^2$= 6820340	$\sum(x-x^{-})^2$= 500,342,91	$\sum(x-x^{-})^2$= 39863408.69

Analysis of variance within groups=116,339,347.5
Analysis of variance between groups statistics: Grand mean=622.7 , Axis 1: x^{-} =9672.1 , Axis 2: x^{-} = 85,925.97 , Axis 3 : x^{-} =378,691.6 , Axis 4 : x^{-} =599,766.1
Estimate of the analysis of variance between groups=358,016.59, F –ratio=116,339,347.5/ 1,074,049.77= 108.3 Significance level = .05 , the critical value = 2.93
1-degrees of freedom for the estimate of the variance between groups = 29
2- degrees of freedom for the estimate of the variance within groups = 3

Central station of urban Khartoum town comes first on ranking of places by level of noise pollution (table 1). Government policy of redistribution of focal points produced new centers of public transportation stations. Here, we identify some famous focal points such as the Mina Bari, Suq Markazi and Suq Shabi. These places work as convergence and divergence points for all transportation routes working within urban Greater Khartoum which includes, Khartoum, Omdurman and Khartoum north towns.

Table (1) also shows higher levels of noise pollution to coincide with central nodal places and cross points. In the cross points, numerous public transportation routes meet together. The remarkable example is the University of Khartoum underpass which occupies the second rank in table 1. Such points are meeting places for crossing transportation routes working between the three towns of Greater Khartoum. The mouths of the bridges are also places of expected high rates of noise pollution. Omdurman new bridge (Ingaz Bridge) at the side of Khartoum town is a point of meeting for those public transportation vehicles going to and coming from Omdurman town to various parts of Khartoum town.

The confirmation of spatial differences between the four main transportation axes studied here is done by running the analysis of variance in table 3. Since the calculated value of F-ratio equals 108.3 and is bigger than the critical value of 2.93 at the significance level of 0.05, we can accept that these levels of noise pollution are dissimilar and statistically different within these four axes.

Results of this paper predicted the contribution of Mini Buses of 15-25 passengers' capacity of public transportation vehicles by 72.15 dB in environmental noise pollution in urban Khartoum town. The situation will exacerbate if private vehicles, taxes, trucks, etc. are taken into consideration, where Khartoum town would certainly be close to the level of threshold of pain (figure 1). This is particularly in situations of increasing rate of modernization and accelerating growth of population. However, modernization is seen in multi storey houses, increased private car ownership through Banks' loan system, changing life style, etc. Rate of population increase in Greater Khartoum was 4.92 in 1956, increased to 7.76 in 1973, and to 8.75 in 1983 to reach 13.7 in 1993 (MFEP 1956 – 1993). Population mean density in Greater Khartoum was 8.8 in 1983. The number of persons per square kilometer was 55.6 persons in 1973 and increased to 85.5 in 1983 and to 169 persons in 1993. In addition, Khartoum state accepted 39% of internal migration of the country in 1983 and 45% in 1993 (MFEP 1956 – 1993). This population increase is reflected in the expansion of the city through formal urban residence plans and informal squatter areas (El-Bushra 1995) and consequently higher demand for public transportation. This phenomenon coincides with other Third World countries, where at least 3.3 billion of the world's population live in urban areas (UNFPA, 2008), to represent 47% of the world's population (Tajudeen 'et al' 2006), and is predicted to reach five billion by the year 2030 with 95 percent of this growth will take place in the developing countries.

The results of this paperwork also revealed a reversal relationship between level of noise pollution and road width. Khartoum town's road system composes very few and narrow main roads. From Khartoum' central bus station emerges only seven main roads to connect with all parts of Khartoum town and with Omdurman and Khartoum north towns. Similarly, there are only three dry bridges, and one underpass. Other factors responsible for congested traffic and consequently higher rates of noise pollution are timing of universities, school, labor force working hours, concentration of services in the city center, passing of connecting roads between the three towns of Greater Khartoum by the city center of Khartoum town. This problem of noise pollution in urban Khartoum town is not exceptional from other urban centers of the world.

The noise level of 72.15 decibels" n ur'an Khartoum town includes somehow equals many urban centers worldwide where 19 countries that had submitted road transport data to the European Environment Agency (EEA), depicted an average of 55 decibels or higher than the 45 dB recommended by World Health Organization as safe noise level (WHO, 1997). There are wide discrepancies on noise levels worldwide. Metropolitan areas in India usually register an average of more than 90 dB. Mumbai is rated the third noisiest city in the world (India Together 2009). Tarulescu (2007) studied traffic noise pollution in Brasov, in Romania, and found that in some of the studied intersections, the medium level of noise pollution (Leq) is frequently over 70 dB, and for the year 2020 they forecasted a duplication of this value. The average level of Leq of all urban zones in Belo (BH) city in Brazil was 69.5 dB, and that the noise of motor vehicles is what contributes more to noise pollution (Alvares et al, ''Date not specified''). The study of environmental noise pollution in city of Curitibi, Brazil, found that 93.3% out of the locations display, during the day, extremely high values of equivalent sound level over 65 dB, and 40.3% out of the locations measured display during the day extremely high values of equivalent sound levels over 75dB (Henrique et al

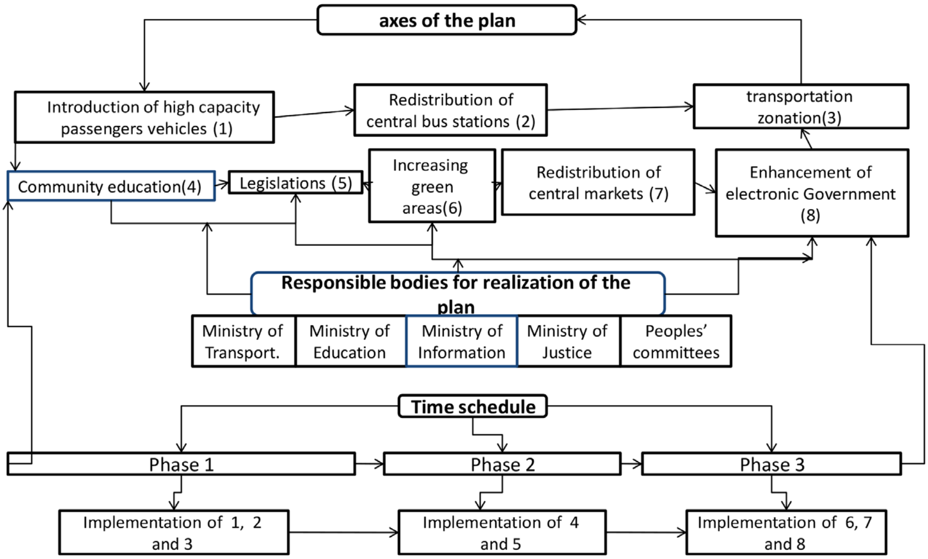
2003). The study of environmental noise pollution in city of Curitibi, Brazil, found that 93.3% out of the locations display, during the day, extremely high values of equivalent sound level over 65 dB, and 40.3% out of the locations measured display during the day extremely high values of equivalent sound levels over 75dB (Henrique, 2003).Noise intensity levels at various locations in Karachi show the highest record at peak time as 88.89 dB and the lowest record as 63.65 dB (Mehdi" Date not specified"), while in Lahore recorded 110 dB (WHO,1997). However, 20% of the European Union's population suffered from noise levels which may be hazardous due to annoyance, sleep disturbance and cardiovascular changes (WHO,1997).In London noise pollution recorded 78.5 dB and in Newcastle upon Tyne it recorded 80.4 dB (Widex Noise Report 2008), while it recorded 88 dB in Cairo recorded 88. dB and 74 dBi in Amman (WHO, 1997).

Conclusions:

Problem of noise pollution in urban Khartoum town is a facet of its growth and development since huge number of urban populations lives there to be served by public transportation vehicles. Spatial variations are quite evident on levels of noise pollution. Central bus stations and some main transportation axes have higher levels of noise pollution as being related to excess Mini Buses, number of journeys and road width. The increasing rate of modernization and trends for private car ownership will demarcate the future of increasing noise pollution in urban Khartoum town. To curb the impacts of noise levels in urban Khartoum town a concise clear plan can be proposed. The plan is outlined in figure 4 with its main axes, the responsible bodies for its realization and its time schedule.

The main axes of the plan included" theintroduction of higher capacity passengers' transportation vehicles with low noise engines; redistribution of central bus stations; transportation zonation; community education; legislation on permitted limits of noise levels; increasing green areas; redistribution of central markets and enhancement of the electronic Government (fig.4). The responsible bodies for the realization of this plan include Ministries of Transportation; Education, Information and Justice as well as the Peoples' committees at the community level. The time schedule included three phases for gradual successive implementations of the proposed axes in order to curb noise pollution in urban Khartoum town.

Figure (4): Plan for curbing noise pollution impacts in urban Khartoum town



Introduction of higher capacity passengers' transportation vehicles with low noise engines instead of the low passengers' capacity ones will reduce noise levels by nearly 1/3, since there will be replacement by 1 for 3 per vehicle, regardless of engine type. Redistribution of central bus stations and transportation zonation will divide the town into sectors and this will evenly redistribute transportation vehicles. However, widening of roads and solving problems of traffic congestion are integral parts to these three axes. Community education will inform people about transportation network and health hazards of noise pollution. Governmental legislations on permitted noise levels will protect related regulations on organizing transportation. Increasing green areas will reduce noise pollution as confirmed worldwide. Redistribution of central markets within the town will create new focal points that cut down population movements towards the city centre. This can be further enhanced by the introduction of electronic Government which will provide services from remote.

Realization of this proposed plan depends on collective work of the entitled Ministries in figure 4. Operation, modernization and organization of transportation network and vehicles is the responsibility of Ministry of Transport. But, this cannot work without education and media. Schools, TV, Radio and Newspapers can transfer information and knowledge about transportation network, traffic legislations and hazards of noise pollution. Ministry of Justice protects legislations on the permitted noise levels and execute penalties. Duties of Peoples' committees should focus on transferring information to local communities about transportation and noise health hazards by enhancing youth clubs, religious men and women.

Implementation of this plan can be stepped wisely. In the first phase it is necessary to provide the infrastructure for noise levels curbing by the introduction of higher capacity passengers' transportation vehicles with low noise engines, redistribution of central bus stations and zonation of Khartoum town. Secondly, is community awareness about transportation, noise pollution and legalization. Thirdly, is the increasing of green areas, redistribution of central markets within the town and enhancement of electronic Government.

By that way it is expected to reduce noise levels in urban Khartoum town but, increasing GNP of the country by introduction of petroleum into the export list of the country, increasing per capita share of national income and cease of war in southern and western Sudan would certainly hold more hopeful and promising future for the country as a whole within which the controlling of noise and gas pollution is possible.

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7

Assessment of nutritional status of children less than 10 years old in rural western Kordofan, Sudan

7

Assessment of nutritional status of children less than 10 years old in rural western Kordofan, Sudan(1)

Although Sudan is rich in natural and human resources, 77.5% of the households surveyed in north Sudan were on or below the poverty line (MOL/ILO, 1997). The UNDP (2005) reported 75% of north Sudan population as poor. The majority (80%) is concentrating in rural areas where 30% of them suffered from extreme poverty. However, malnutrition is a real health problem in the country (tables 1).

Table (1) Malnutrition in Sudan

Reference	Low weight/age		wasting		stunting	
	prevalence	severe	prevalence	severe	Prevalence	severe
SERISS,1988	-	-	14.1	1.7	32.1	12.6
SMCHS, 1995	34.0	11.3	13.0	3.0	33.0	17.0
Magboul et al,2002	26.6	-	9.8	-	32.3	-
FAO/WFP,2005/06	41.0	15.0	-	-	41.0	15.0

Nutrition security strongly connected with food security, and is achieved at the household level when its members' food intake provides the recommended levels of protein, vitamins, minerals and energy. Food security is "a situation exists when all people at all times have sufficient access to sufficiently safe and nutritious for a healthy and active life" (FAO, 1996). Food insecurity is "a limited or uncertain access to foods of sufficient quality or quantity to sustain a healthy and active life" (Mohamed et al., 2004). Moreover, Thomas et al. (1997) differentiated between chronic and transitory food insecurity. The first type occurs when individuals or groups suffer from food insecurity at all times.

(1) Co-authored with Hashim Sulieman, University of Khartoum, Department of Healthy and Therapeutic Nutrition.

The second type associates with a temporary decline in access to food due to temporary adverse circumstances. Transitory food insecurity was further divided into temporary and seasonal types. The first one is unpredictable, e.g., drought, unemployment. The second one usually follows a regular pattern of inadequate accessibility to food, i.e., agricultural season. Food insecurity can be related to fluctuation of production and price affecting the food or non-food sector leading to fluctuations in real income producer within the community (Valdes et al., 1981). Natural disasters, armed conflicts and hunger are also responsible for food insecurity (Alexander, 1997; Young, et al 2001; Hinrichs, 2002).

Nutrition insecurity leads to protein – energy malnutrition and usually assessed by surveys. Nutrition status is measured directly by dietary surveys, biochemical data, and anthropometric and clinical examination methods. While food adequacy is necessary for a household to achieve nutrition security, but it is not in itself sufficient. This is because some other key contributors to good nutrition are also important, such as poverty reduction, female education and a healthy environment. However, some researchers view poverty as the main cause of malnutrition while some others believe in malnutrition eradication without reduction in poverty pointing to well-nourished children living in very poor households. Female education is positively correlated with reduction in infant mortality rate (UNICEF 1990; Devads et al.; 1980; Bhuiya et al.; 1986, Brahman 1988). Environment health largely determines nutritional status either through infections, depletion of nutrients and illness or vice versa. (UNU 1979, Osmani 1997, Biesel, 1984).

Data was collected during August – October 2005. The villages were selected randomly and included Abu Serour; Rahad el Selik; Wad Gudiem; Um el Badri; el Karanik and Maryoud (Figure 1). The area was chosen due to its fragile environment with expected food problems. Population number is 92368 persons distributed in 14512 households (MEUASP, 2005). Cluster sampling is used for selection of rural villages by using probability proportional to size (PPS), and secondly for selection of the households from the ever-selected villages. The sample size was calculated by the formula:

$n = t^2 pq/d^2 \times deff.$

Where: n is the sample size, t = 1.96, q= 0.50, p=0.05, d =0.08 and Deff. =1.5 (design effect).

Therefore: n = $(1.96)^2$ x0.05x0.50/ $(0.08)^2$ x1.5=225

Clusters = sample size/desired number of households in a cluster = 225/20= 11.25 (all clusters).

Since there are 92368 persons distributed in 14512 households, this gives 25431 households.

Then rural clusters= 14512/11.25/25431=ca.6. So rural households included = 20x6=120

The study covered dietary and anthropometric assessments of children less than 10 years old. Dietary assessments determined individual and household food consumptions. Anthropometric assessments involved physical measurements of the body such as weight, height, etc. Therefore, there are weight/height, weight for age, height for age and weight for height data, in addition to their sub-classifications (Gomez et al., 1955, WHO 1995, Waterlow et al., 1977). Underweight, wasting, and stunting, in addition to measuring food frequency as consumption patterns during a week, were used to assess the nutritional status of children less than 10 years in the study area.

Underweight is a measure of wasting or stunting or both. Weight measurements, which were taken to the nearest 0.1 kg, were taken by electronic scale. Subjects were weighted barefooted wearing minimum clothing. Salter scale was used for children less than two years old who are unable to stand. Height of children less than 2 years old was measured while they are lying on their backs with stretched legs and heads up. A wooden scale is used for children whose ages were 2 to less than 10 years old. Evaluation of nutritional status for children less than 10 years old was done by Z- score for the parameters of underweight (weight/age); wasting (weight/height); and stunting (height/age). The criteria used is normal (≥I SA) and undernourished (≤ - I SA). The (≤ - I SA) criterion is further divided into mild (-1 to – 2 SD); moderate (12 to -1 SD) and severe (≥ -3 SD).

Measuring food frequency as consumption patterns during a week was recorded as consumption/day; every other day; twice/week; one/week; rarely or none. Household food intake (the 24-hour recall) was recorded in domestic measures and converted to weights. Nutrients intake was calculated using food consumption tables (Sukkar 1985, Boutros 1986). Individual food intake is calculated as an average per individual since all family members eat together, and it was evaluated as energy and protein intake.

Recommended allowance "RDA" calculation is based on FAO (1994[B]) RDA, and the figure for protein intake based on high fiber diet was applied since it represents the dietary pattern of the subjects covered by the study. An average figure was calculated from the RDA of household members above five years old to obtain the RDA per household for energy and protein. Adequacy intake based on households' RDA was calculated by: adequate ≥ 80% and inadequate ≤ 80%.

The study area is part of north Kordofan state (figure 1). It has a semi-arid environment with climatic fluctuations and average annual rainfall of 200 mm. Sand dunes and sandy soils are dominant and natural vegetation is sparsely. Children less than 10 years constituted 36.5% of the total population distributed as 17.8% males and 18.7% females. Average household size of 4-6 person included 50.8% of total households surveyed, while 7-10 person households represented 36.7%. Male headed households represented 44.1% of total households. Illiteracy is high by 75.9% among households surveyed, who are mainly peasants. They cultivate sorghum (Dura) and bulrush millet (Dukhn), sesame and groundnuts. Monthly income is distributed as 59.2% earns less than 200 SDG, 30.0% earns 200-300 SDG. They generally fall below poverty line as their incomes are far less than one USD per day. The so-called higher income groups (301-500 and ≥ 500 SDG) totaled 10.8%

Figure (1): location of Sudan and the study area (western Kordofan state)

For the Assessment of the nutritional status, Dietary and anthropometric evaluations are used to assess the nutritional status of children less than 10 years old in the study area.

Dietary evaluation (macro level):

Average contributions of carbohydrates, protein and fat to total energy were 56.2%, 9.3%, and 34.5% respectively (table 2). Fat was slightly higher and carbohydrates lower than the recommended values (Katch et al 1983). Less meat was consumed here but, the higher fat figure was due to consumption of more groundnuts and groundnuts oil as it is produced, pressed and refined locally. Comparing macronutrients daily intake in the study area with the study by FSU (2005) puts the study area below as there are less protein, carbohydrates and lower energy intakes (1803 kcal vs. 1962 kcal) and above as there is fatter intake. Energy obtained by higher protein and carbohydrates intakes by FSU study was more than double the value obtained by excess fat intake in this study.

Table (2): Parameters of Nutrients' contribution (%) to total energy intake & recommended range (R); Macronutrients' mean daily intake and Cereals contribution to total energy (kcal) and protein (g) intake in the study area.

(1) Nutrients' contribution (%) to total energy intake & recommended range (R)		
Carbohydrates	56.2	R= 55-60
Protein	9.3	R= 10-15
Fats	34,5	R= 25-30
(2) Macronutrients' mean daily intake		
Energy (kcal)	1663±383*	1803±449
Protein (g)	37.7±11*	42.0±14
Carbohydrates (g)	232.6±70*	261.4±80
Fat (g)	63.5±23**	64.5±25
Animal protein (g)	9.8±4.6*	13.1±6.3
Animal fat (g)	7.5±9*	12.2±11
(3) Cereals contribution to total energy (kcal) and protein (g) intake		
Energy	774.7±163*	824.3±172
% of total energy	46.5	45.7
Protein	16.1±3.9**	19.0±6.8
% of total energy	42.7	45.2

Source: Fieldwork (2005)

Cereals highly contribute to energy and protein intake in the study area, a situation similar to rural Philippines where 361g/person/day are consumed there (Florentino 1999). Frequency of daily cereals' product consumption was higher for sorghum porridge "Asida", which provides less energy due to its high moisture content. This seems the only viable explanation for higher cereal products in rural households but there is less energy and protein intake. Cereals products provided 42.7% of total energy and 45.2% of total protein (table2). Animal protein sources such as meat and milk provide less than the recommended 55.3g by FSU. Here, meat is consumed by 70.5% of the surveyed households.

Moreover, nutritional adequacy can be roughly assessed from energy and protein content of the daily diet relative to the recommended allowances (RDA). Inadequate energy intake means that the quantity of food consumed was below optimum need as the energy value is derived from all three macronutrients. The rural households of the study area consume diets low in quantity and intermediate in protein quality as the major source was plant protein which produced locally.

Anthropometric evaluations (micro-level):

Table (3) shows anthropometric evaluations for children less than ten years old in rural western Kordofan. Underweight children represented 58.3% here, which is almost similar to the 50.0% cited by FAO/WFP (2006) for pre-2001 studies for north Kordofan state. However, it was higher than the most recent report (SHHA, 2006) of 42.9% (35.0% moderate and 7.9% severe) for north Kordofan state. The result was also higher than all previous studies carried out in Sudan, although it is similar to that of El Jaloudi (2000) for children less than five years old living in poor urban Khartoum state. Yet, severe under nutrition was reported higher in west Kordofan than in north Kordofan (MICS, 2000). In addition, the difference in prevalence rate is possibly due to geographic reasons. A drop from 50.0% to 42.9% indicated to better food intake and less infectious diseases, so probably this was not the case in our study area as 51.8% of the total households were food insecure.

Table (3): Nutritional status of children under ten in rural western Kordofan

parameter	*Nutritional status*	.No	%
Wt/age[a]	Normal	60	41.7
	Moderate	59	40.9
	Severe	25	17.4
P=0.194	**total**	144	100.0
Wt/height	Normal	85	59.0
	Moderate	32	22.2
	Severe	27	18.8
P=0.003	**total**	144	100.0
Height/age	Normal	100	69.4
	Moderate	20	13.9
	Severe	24	16.7
P=0.001	**total**	144	100.0
Wt/age[b]	Normal	63	45.9
	Moderate	47	34.3
	Severe	27	19.7
P=0.025	**total**	137	99.9
Wt/height[b]	Normal	54	39.5
	Moderate	46	33.5
	Severe	37	27.0
P=0.064	**total**	137	100.0
Height/age	Normal	118	86.1
	Moderate	12	8.7
	Severe	7	5.1
P=0.121	**total**	137	99.9

A=≤ 5, b= ≤ 10 , Source: Fieldwork (2005)

Wasting prevalence was 37.9% (19.6% as moderate and 18.3% as severe) while in the SHHS (2006) for north Kordofan state it was lower (16.0% total: 13.5% moderate and 2.5% severe). Figures obtained in this study were also higher than those obtained previously by El Jaloudi (2000) which were, 18.7% moderate and 2.2% severe. In all relevant studies severe wasting was ≤ 3% but, however our study shows higher level. Wasting was prevalent in the study area (41.0%). Within each level of wasting, 74.4% is moderate, and 67.5% is severe. Since the survey was carried out during the pre- harvest season (August/October), a period of food scarcity in such rural areas, there will be less food intake and by so more incidence of wasting is expected as the index indicated to recent low food intake in addition to poverty.

A stunting is a measure of chronic under nutrition. Stunting prevalence in the study area was 23.7% (12.3% moderate and 11.4% as severe) which was lower than all previous studies for total or severe cases (table 1), which were 51.0% for north Kordofan and 47.7% for whole the Sudan (SHHS,2006). It was even lower than the figure of Sub-Saharan Africa of 38.0% (UNICE, 2008), or the 55.9% for rural Ethiopia (Yousuf, 2000). The prevalence of underweight was rather similar to those found for fewer children aged less than five years old in the study area. Underweight was prevalent by 54.1% and constituted the majority within the moderate (68.1%) and severe cases (81.8%).

Wasting for all children was 55.9%, 32.2% moderate and 23.7% severe. Wasting was higher for children less than five years old at all the three levels especially severe wasting, which is probably an indication of even lower food intake at the fieldwork time. Wasting prevalence was higher (60.5%), and within these rural households, it was found to be higher within the moderate (67.6%) and the severe (74.0%) cases. Stunting prevalence was 11.4% (7.1% moderate and 4.3% severe). Generally, higher prevalence rates for moderate and severe stunting were recorded for these rural children. However, one in every seven children was wasted and one is every three was stunted in north Sudan (SERISS, 1988).

Factors influencing nutritional status in the study area:

Factors considered determining the nutritional status of children less than 10 years old in the study area were modeled in figure 2. Environmental factors somehow determine food production, food availability and population affordability to buy food. The study area is environmentally fragile. It lies within "very high risk" zone of desertification designated by the United Nations (UN 1977). Its average annual rainfall values decreased markedly since early sixties (El Gamri, et al., 2009). Natural vegetation is deteriorated and total biomass gets over-exploited by grazing and browsing animals. As a result, vegetation may still appear quite dense after heavy grazing, whereas in fact selective grazing has eaten out many of the palatable species and reduced the carrying capacity dramatically (Davies 1987).

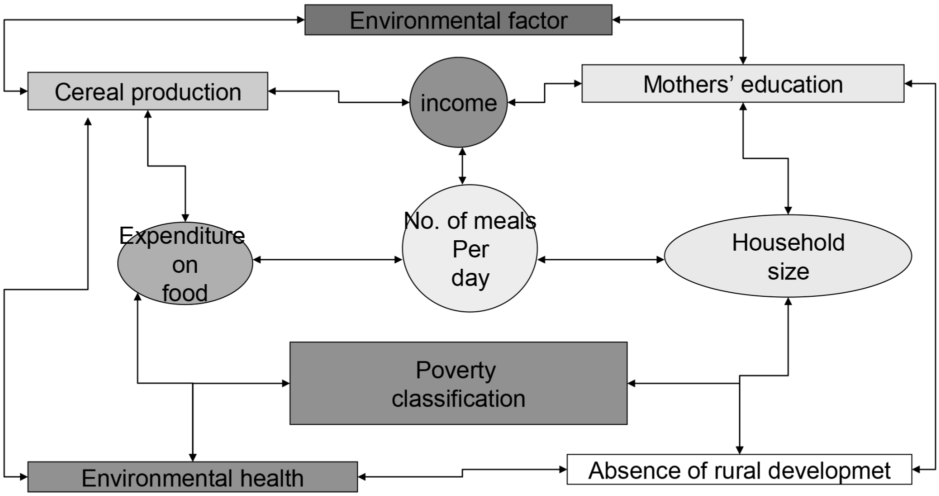
Resident population of the study area used to increase their cultivation area since coefficient of variation of the annual rainfall is about 30% the area cultivated and the productivity varies widely from one year to another (MOIWR 1999). They clear wide areas to grow crops and so compete with livestock for both land and water. In 1973, the Agricultural Conference recommended rain-fed cultivation south of 300 mm rainfall line to stop environmental degradation. However, people are still cultivating areas north of that line (Ibrahim and Al/Ghani 1983), causing desertification (Iskander1989) and deterioration of the food system where about half the population of sub-Saharan Africa is living below the poverty line, with both numbers and percentage on the increase (Alredaisy & Davies 2001).

Fieldwork results depicted higher level of protein intake implies consumption of better-quality protein with increasing income. There is significant increase in energy and protein intakes with increasing incomes and a similar increase that was highly significant were recorded for protein (Ibrahim, 2008). In these rural households, energy and protein intakes also increased with increasing income. The level of significance was lower for energy, probability 0.042, and was significant for protein with probability of 0.053. Comparison between lowest income group and highest one depicts an increase by 34.6% in energy and 41.3% in protein. Higher income groups (301-500 and ≥ 500 SDG) totaled 10.8%. By that way, 89.2% of the rural household did not benefit from increasing income that led to increasing intake of energy and protein. Many studies in Sudan referred low weight, stunting and wasting among young children to unequal income distribution, vertically between incomes and horizontally between rural and urban areas (UNDP 2006).

Some researchers are convinced that increasing income leads to increasing food intake (Strauss 1984, Maxwell et al 2000) while some others believe that poor households spend their additional incomes on more expensive foods such as finer cereals, meat or dairy products which do not necessarily yield more energy. The fieldwork results support the first assumption that increasing income had positively increased energy intake, and therefore increased protein intake. Income was also positively correlated, probability of

0.000, with the nutritional status. Less income resulted in prevalence of undernutrition in the study area. Thus, decreasing income led to marginal or sub-optimal intakes of energy and protein resulting in more prevalence of under nutrition.

Figure (2): Factors influencing nutritional status of children ≥ 10 years old in a rural environment of western Kordofan
source: Fieldwork (2005) and UNDP/WFP (2006)



Increased food expenditure had significantly increased energy and protein intakes in the study area for both energy, probability of 0.042, and for protein with probability of 0.025. In the latter case, such an increase is not as important as that for those whose food expenditure amounted to ≥ 100 SDG, who constitutes 9.1% of the households, while for the remaining 90.9% there was practically no increase. A significant relationship exists between food expenditure and under-nutrition prevalence in the study area with probability of 0.004. This commensurate with the fact that food expenditure positively affected energy and protein intake and thus the energy status of the body.

As far as number of meals per day is concerned, it is expected that more energy and protein will positively correlate with three meals per day other than with two meals. Meals provided more energy was not detected in these rural villages where the probability was 0.104. Increase in protein intake was not significant for these rural households where the calculated probability was 0.145. The noticeable increase in energy here can be attributed to poverty, where 95.8% of the households earned ≤ 5 US$/ day (table 4). Number of meals per day influences energy and protein intakes, a positive relationship confirmed in the study area by a probability of 0.006. Energy intake reversibly decreased with increasing household size, where the calculated probability was 0.042 (table 4). The decrease in kcal was slightly low here (17.3%). Protein intake also decreased with increasing household size; probability was 0.000. Decrease in protein was high in these poor rural areas (26.7%) as they had big families. These factors point out to decreasing protein intake with increasing number of persons sharing the common dish which its protein content was originally low. Positive relationship exists between household size and nutrition status in these rural areas and the calculated probability was 0.018. Since energy and protein intakes were less and the households are big enough, it is expected to have positive relationship between household size and nutrition status.

Mothers' literacy positively effects low weight- for- age compared to illiterate mothers who have more stunted children in Sudan (FAO/WFP, 2006). Magboul's et al. (2002) results revealed that wasting was 11.3% in Khartoum and Omdurman towns, while it was 4.9% in Khartoum north, a result similar to SERISS (1988) and SMCH (1995) results where mothers' educational level was remarkably influential. However, other factors influencing nutrition status of children less than 10 years old in the study area might include those operating at the national level. They are absence of social development, insufficient productive capital investment in agriculture and industry (UNDP 1998), ill-conceived development policies neglecting rural development (figure 2) and armed conflicts.

Table (4): Factors determining the nutritional status of children less than 10 years old in rural western Kordofan based on fieldwork (2005

parameters	Rural	
	No.	%
1- **Income** (SDG)		
≤200	71	59.2
200-300	36	30.0
301-500	10	8.3
≥ 500	3	2.5
Total (P=0.000), P means probability	120	100.0
2- **Food expenditure** (SDG) / day P= 0.000		
≤ 5	29	24.2
5- ≤ 10	80	66.7
10- ≤ 15	10	8.3
≥ 15	1	0.8
total	120	100.0
3- **Number of meals/day** P= 0.000		
Two	96	80.0
Three	24	20.0
total	120	100.0
4- **Household size** P= 0.223		
1-3	8	6.7
4-6	61	50.8
7-10	44	36.7
≥ 10	7	5,8
total	120	100.0
Poverty classification US$/ day		
≤ 5	115	95.8
5 - ≤ 10	-	-
10 - ≤ 15	5	4.2
≥ 15	120	100

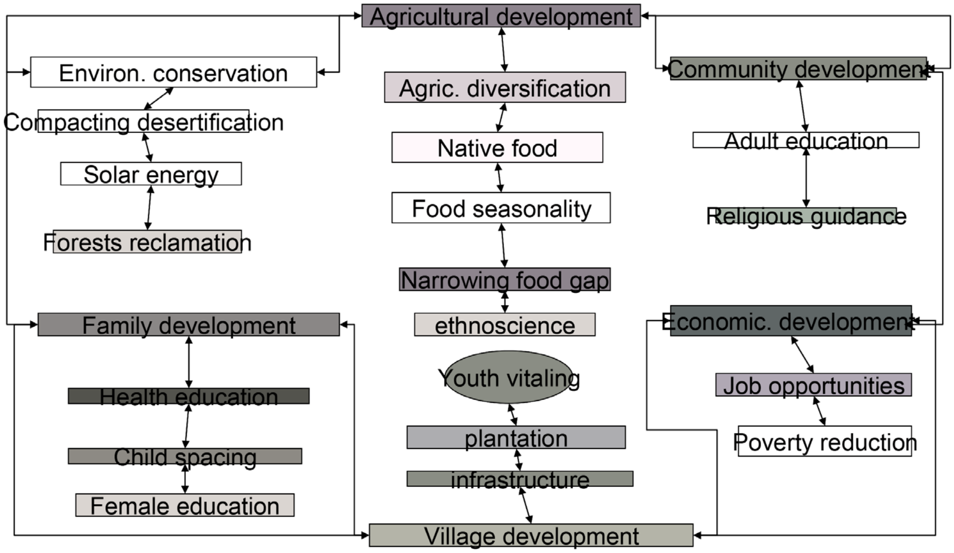
Vulnerable groups to nutrition insecurity in Sudan are those whose food intake provides less than that recommended for refugees and internally displaced groups (IOM, 1995). Cambrez et al (1998) excluded areas of armed conflict and identified areas nutritionally insecure in Sudan as to include rural areas of low crop and animal production; areas of low purchasing power and education and knowledge; areas of low access to health facilities and areas with low access to water especially during dry season, which all are tangible in the study area. Food insecure groups in Sudan were identified by FAO/WFP (2006) as those internally displaced people; vulnerable residents who were indirectly affected by the influx of internally displaced population in their communities and returnees numbering 4 million internally displaced population and 600,000 refugees almost all from South Sudan.

The fieldwork results in rural western Kordofan are agreeing with national surveys. Rural communities in Sudan are generally suffering from lack of socioeconomic and community development projects, a situation further exacerbated by adverse climatic conditions. The majority of rural population of Sudan lives in somehow fragile environments being vulnerable to crop failure and animal loss. These situations determine the nutritional status of the population in general and children of less than 10 years old in particular who are mostly risky to malnutrition and infectious diseases. The cycle of malnutrition- infection – depletion of body nutrients works with the sublevel household food intake, illiteracy, low income and big family size. These deplete family resources and usually fail to meet nutritional needs of such vulnerable age group.

The general conclusions of this study are that low weight, wasting and stunting have characterized the nutritional status of children less than 10 years old in rural western Kordofan. They were thoroughly affected by their households' general situation. There are less animal protein, vitamins, minerals, and abundant cereal were consumed, households are big enough, low food expenditure and high illiteracy.

However, the future of these communities needs an intervention for adequate child and community nutrition. This intervention is suggested in a model based on available resources in the study area (figure 3). The model included six integrated strategies. They were agricultural development; environmental conservation; community development; economic development; family development and village development strategies.

Figure (3): A proposed model for the promotion of the nutritional status of children underten in rural western Kordofan



For agricultural development the model suggested crop diversification to increase cash income among peasants; utilization of native food for child nutrition; benefit of seasonal food surplus by storage, developing ethno-science to promote agricultural practices. The strategy for environment conservation will boost agricultural development as it included combating desertification, reducing overgrazing and over wooding by introduction of solar energy and reclamation of forests. Community development strategy can integrate with family development strategy, female education, health education and child spacing. Economic development increases household incomes by creating job opportunities and poverty reduction. Village development strategy should develop youth capacity for social work such as tree plantation of the village neighborhoods. Basic infrastructure including schools, youth clubs, medical dispensaries and roads will upgrade the study area for better linkages with other parts of the Country.

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8

Nutritional Status of Children Less than Five-Year-Old Suffering Anemia and Night Blindness in Khartoum State, Sudan

8

Nutritional Status of Children Less than Five-Year-Old Suffering Anemia and Night Blindness in Khartoum State, Sudan(2)

Nutritional discrepancies are widely spreading in Developing World, as it threatens individuals and communities with nutritional deficiency diseases where in Sudan, for example, among 10 children one dies before completing five years due to these diseases (UNICEF, 2008). Malnutrition due to micro nutrients (hidden hunger) deficiency represents the most form spreading where more than two billion are suffering from it in the world. And more than 250,000 children are affected by night blindness every year, and more than half dies approximately. In Sudan, the estimated rate of prevalence of hidden hunger is 4.8% while the rate of anemia (iron deficiency) for children less than five years old is about 55.1% (National Ministry of Health, 2008; World Health Organization, 2009). These cases distribute with different percentages in Khartoum State, 76% in Greater Khartoum, 75.3% in Greater Khartoum north, and 23.9% in Greater Omdurman (National Ministry of Health, 2008; World Health Organization, 2009). Nutritional deficiency among children less than five years old contributes by around 51% among causes of death (UNICEF, 2008).

Camber and el Magboul's study identified areas nutritionally insecure in Sudan as to include rural areas of low crop and animal production; areas of low purchasing power and education and knowledge; areas of low access to health facilities and areas with low access to water especially during dry season [4]. Food insecure groups in Sudan were identified as those internally displaced people; vulnerable residents who were indirectly affected by the influx of internally displaced population in their communities and returnees numbering 4 million internally displaced population and 600,000 refugees

(2) Co-authored with Haram Omer El Hag Saeed, Ministry of Health, Gezira State, Rufaa Nutrition and Maternity Office, Sudan

almost all from South Sudan [5].Nutrition insecurity leads to protein – energy malnutrition and usually assessed by surveys. Nutrition status is measured directly by dietary surveys, biochemical data, and anthropometric and clinical examination methods. While food adequacy is necessary for a household to achieve nutrition security, but it is not in itself sufficient. This is because some other key contributors to good nutrition are also important, such as poverty reduction, female education and a healthy environment. However, some researchers view poverty as the main cause of malnutrition while some others believe in malnutrition eradication without reduction in poverty pointing to well-nourished children living in very poor households. Female education is positively correlated with reduction in infant mortality rate [15, 16]. Environment health largely determines nutritional status either through infections, depletion of nutrients and illness or vice versa [17, 18, and 19].

The methodology focused on collection of relevant data to identify factors responsible for the spread of nutritional deficiency related diseases, anemia and night blindness among children less than five years old in Khartoum State. The fieldwork and investigations took place in February 2009 through to February 2012 in big specialized child's hospitals in each of the three towns. They were Ga'far Bin Oaf Hospital in Khartoum, Child Emergency Outpatient of Omdurman Hospital, and Ahmad Grasim Hospital in Khartoum north.

A questionnaire was designed to collect relevant nutritional data concerning children suffering anemia and night blindness, as well clinical symptoms of anaemia and night blindness. The following formula is used, based on that rate of prevalence of nutritional deficiency diseases in Khartoum State is 10% (Khartoum State, Ministry of Health 2009), to estimate sample size: -

$$n = \frac{Z^2Pq}{d^2}$$

n = sample size; Z = 1.96; P = prevalence rate of nutritional deficiency diseases; q = 1 – P; d = 0.05

The 10% prevalence rate of nutritional deficiency diseases in Khartoum State is used to get q which gave 138 individuals, as follows:

$$n = \frac{(1.96)^2 \times (1 - 0.1)}{(0.05)^2}$$

$$n = \frac{3.8416 \times (0.9)}{(0.05)^2} = \frac{3.8416 \times 0.9}{0.0025} = 138$$

To determine the share of each Hospital from this sample size, the equation of distribution in proportion to size of population (children suffering nutritional deficiency diseases) in each hospital is used, as follows:

Cases of malnutrition in Khartoum (15628 = $\frac{100 \times 15628}{49003}$ =32

Cases of malnutrition in Khartoum north (12602) = $\frac{100 \times 12602}{49003}$ = 26%

Cases of malnutrition in Omdurman (20773) = $\frac{100 \times 20773}{49003}$ = 42%

The total cases of malnutrition in Khartoum State = 49003

The share of each town (hospital) of the sample size is determined as:

Khartoum = $\frac{138 \times 32}{100}$ = 44

Khartoum north = $\frac{138 \times 26}{100}$ = 36

Omdurman = $\frac{138 \times 42}{100}$ =58

Before conducting fieldwork, the two diseases under investigation were determined by taking samples of the blood of the sick children through the Hospital technicians and by one of the researchers, in addition to the files of the sick children. Symptoms of the two diseases were used also which is done by doctors during their routine rounds in the hospital. Following that, the questionnaires were filled with mothers of the sick children whom were chosen purposively because sick children with different diseases, are not usually separated from each other in these hospitals.

Hemoglobin measurement was done by using Colorimeter by taking 20 micro millimeters of the blood of the 138 sick children in a test tube, and 4 milliliters of Drabakin was added with 14.8 15 gram/deciliter concentration and fully mixed, left for five minutes to be read by Colorimeter. This gave that,

The result X concentration of solution (Darabakin)/ rate of photo absorption = Hemoglobin gm/Deciliter

Hemoglobin gm/Deciliter X 6.8 (constant factor) = Hemoglobin %

Anthropometric measurements are done using Salter's scale to measure weight versus age for all the 138 children to determine their nutritional status. The nutritional status index of weight versus age is quick and accurate method to know the nutritional status of children less than five-year-old. The evaluation of the nutritional status of children less than five-year-old was done using tables of estimation of rate for children less than five-year-old which is published by World Health Organization. The most indexes used to measure body to estimate nutritional status is weight for age index. Taking the measurement of weight is easier compared to measuring height and enable for more precision. Therefore, this measure is used into observing gradual growth in body volume and organs and helps into detection of early malnutrition.

Food weight measurementis also used which weights 3 kilograms (electronic scale) to measure the amount of food consumed during the day. To know the average of energy, protein, iron and Vitamin consumed relative to the size of the household, children under study were divided into groups, less than one year, 1-3 years, and 4-6 years; and -1 year + 1-3 years, -1 year + 4-6 years, (1-3) +(4-6) years and another group includes all age classes of 1 year + (1-3) + (4-6) years. This classification facilitates comparison between food consumption according to age groups of children less than five-year-old. To know consumption of energy, protein, iron, and Vitamin A relative to the household size, these households were divided into small households less than 4 individuals, medium households 5-9 individuals, and big households more than individuals. This classification facilitated comparison between daily consumption of energy, protein, iron, and Vitamin A according to household size.

Conditions for rejection included all children transferred from other States of Sudan hospitals were excluded and the study restricted to those who live permanently in Khartoum State during the time of fieldwork.

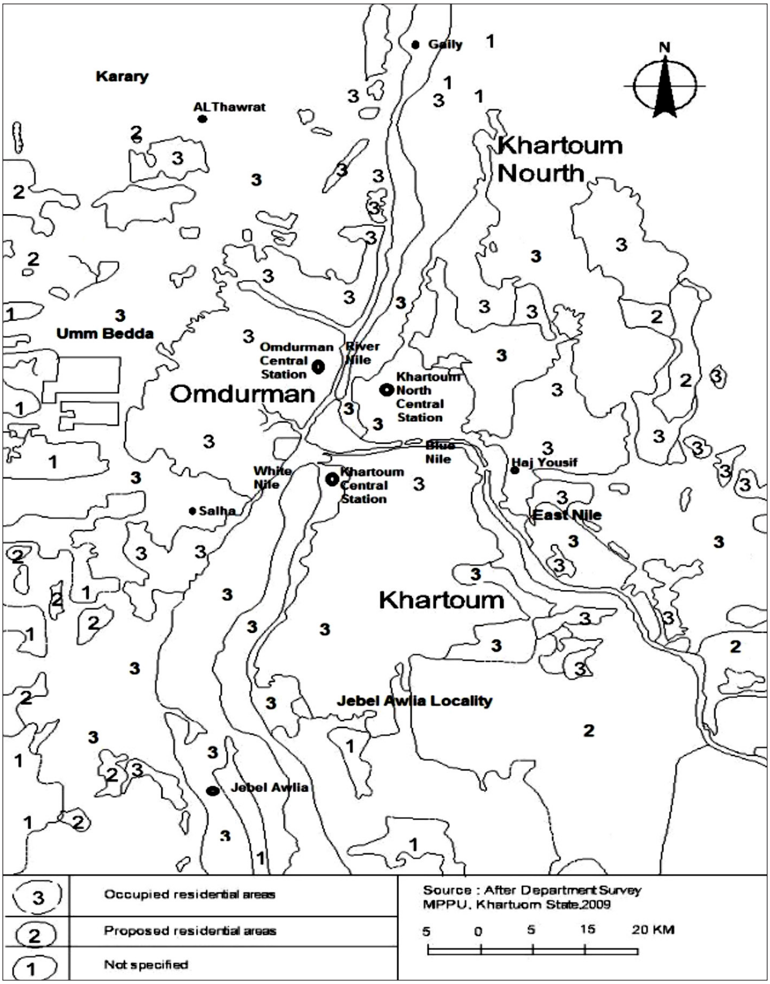

Fig.1. Greater Khartoum: location, localities, and sites of Hospitals

The data was statistically analyzed to calculate Chi – square, correlation

Khartoum States consists of the three towns of Khartoum, Khartoum north and Omdurman (Fig.1) and their rural neighborhood. Rate of population increase in Greater Khartoum was 4.92 in 1956, increased to 7.76 in 1973, and to 8.75 in 1983 to reach 13.7 in 1993 (MFEP 1956 – 1993). Population mean density in Greater Khartoum was 8.8 in 1983. The number of persons per square kilometer was 55.6 persons in 1973 and increased to 85.5 in 1983 and to 169 persons in 1993. In addition, Khartoum state accepted 39% of internal migration of the country in 1983 and 45% in 1993 (MFEP 1956 – 1993). This population increase is reflected in the expansion of the city through formal urban residence plans and informal squatter areas (El Bushra, 1995) and consequently higher demand for public transportation.

Symptoms of anemia and night blindness:

Apparent symptoms of anemia are loss of appetite (87.7%), paleness (93.5%), exhaust, eating clay (29%) and snow (2.9%). The symptoms of night blindness are night blindness (12%); xerophthalmia (20%); Pinot spots (52%); keratomalacia (12%), and Cornea ulceration (4%). Hemoglobin measurement for children suffering night blindness (Table1) revealed that children aged 1–3-year-old suffers less incidence of night blindness compared to children aged less than one year old and children aged 3-5 years old who are equal. This contrasts anemic children, where children aged 1-3- and 3–5-year-old are almost having equal percentage, while children aged less than 1 year old might differ significantly than the previous two age groups. The general striking feature of distribution of night blindness and anemia among these three age groups is that, each age group has ½ of incidence of a disease and the differences are quite minor. The distribution of children suffering night blindness by sex by percent (Table 1), depicts more males are suffering compared to females, who are at the same time more anemic but the differences might not be significant indicating to that both sexes suffer anemia and night blindness.

Table 1: Hemoglobin range measurement (%) among children suffering anemia and night blindness by age and by sex

Age / sex	Night blindness		Anemia	
	frequency	%	frequency	%
-1 year	3	37	31	32.2
1-3years	18	34.8	73	38.8
3-5 years	4	37	9	39.1
Males	60	43.5	15	10.9
Female	53	38.4	10	7.2
Total	113	81.9	25	18.1

Anthropometric measurements:

Table 2 depicts state of malnutrition as indicative to weight of children. Acute malnutrition spreads more among sick children, followed by medium, simple and normal respectively, with significant difference between acute and simple types of malnutrition. Acute malnutrition is a reflection of low nutritional status, and makes the majority of these children vulnerable to infection and childhood diseases. The weight of children indicates to highest malnutrition rate among children aged 1–3-year-old, followed by children less than one year, and lastly 3–5-year-old.

Table 2: malnutrition among children less than 5-year-old in Khartoum State

Malnutrition state	frequency	%
Normal	11	8.0
simple	13	9.4
Medium	27	19.6
Acute	87	63.0
total	138	100.0

Table 3 depicts that rate of malnutrition by age groups was highest among children aged 1–3-year-old, followed by those aged -1-year-old and lastly by those aged 3–5-year-old. The distribution of malnutrition among age group of males identified those aged 1-3 year as the most suffering, and those aged 3-5 year as less suffering. Females are typical to males concerning distribution of malnutrition by age groups. However, females are generally, less malnourished compared to males with a percentage difference of 8.6% (Table 3).

Table 3: Malnutrition by sex by age

Age / sex	sex				total	
	Males		Females		frequen-cy	%
	frequen-cy	%	frequency	%		
-1 year	18	13	16	11.6	34	24.6
1-3years	47	34.1	43	31.2	90	65.3
3-5 years	10	7.2	4	2.9	14	10.1
total	75	54.3	63	45.7	138	100

Nutritional status of mothers during pregnancy and lactation:

Table 4 depicts types of food intake during pregnancy and lactation. When they are pregnant, mothers used to consume vegetables, fruits, milk, cereals, meat, and legumes abundantly compared to less amounts of these food types during lactation. In addition, during pregnancy porridge with sauce; salad with Shatah (hot sauce), and Salad with yogurt are consumed, where some of these food types are concerned with likes and dislikes of pregnant women. Lactating mothers largely depend on vegetables, legumes, meat, cereals, milk, and fruits + sweet porridge which are nutritionally valuable providing protein, energy, iron, minerals, and vitamins. Sweet porridge is a mixture of cereals, sugar, oil, and ghee which activates breasts producing much milk for lactating children. Traditional porridge is made by boiling cereals (*Dura* or *Dukhn*), and usually taken with sauce or milk. Sauce is a mixture of vegetables, meat, oil, and spices. In addition, cereals are fermented and cooked to produce traditional bread (*Kisra*).

Table 4: types of foods during pregnancy and lactation (%)

Types of foods	Pregnancy (%)	Lactation (%)
Porridge with sauce	20.3	0.0
Salad with shatah (hot sauce)	10.9	0.0
Salad with yogurt	9.4	0.0
Vegetables, legumes, meat, cereals, milk, and fruits	56.4	18.1
Vegetables, legumes, meat, cereals, milk, and fruits+ sweet porridge	0.0	81.9
total	100	100

Table 5 depicts that, the majority of mothers did not have preventive and curative doses of Vitamin A, Iron, Folic acid, and Fevol during pregnancy. Lacking taking these elements make mothers and their born infants vulnerable to many diseases. However, this situation might be mild when 61% of the mothers have been vaccinated, 32% partially vaccinated, and only 7% were not vaccinated.

Table 5: Preventive and curative elements taken during pregnancy among mothers of children suffering anemia and night blindness in Khartoum State

Do you take these elements?	Vitamin A				Iron		others			
	preventive		Curative		Curative		Folic Acid		Fevol	
	frequency	%	frequency	%	frequency	%	frequency	%	frequency	%
Yes	16	11.6	4	2.9	47	34.1	2	2.9	29	21
No	118	85.5	118	85.5	91	65.9	134	97.1	109	79.0
total	134	97.1	122	88.4	138	100	138	100	138	100

3.4. Nutritional budget of children suffering anemia and night blindness:

There are 97.1% of interviewed mothers breast feed their sick children after three days following their delivery. The mean of the duration of breast feeding is eleven months. Reasons for not breast feeding included, death of a mother (25%), infection of mother with tuberculosis or psychiatric diseases (50%), or the child is being sick (25%). The majority of the mothers (61.6%) perceive that breast feeding prevents infection to diseases during childhood, while some others (38.4%) are ignoring that. During early infancy of 0 – 6 months, 89.9% of the mothers are breast feeding their children and simultaneously give supplementary food, while 7.2% of mothers depend solely on breast feeding only, and still very few mothers (2.9%) give supplementary food only. For infants aged 6 - 12 months, very few mothers (0.41%) depend on breast feeding as the main source of feeding their children, while 87.7% of them combine breast feeding with supplementary food, and only 10.9% give their children supplementary food. Mothers do not change their child feeding behavioral pattern during first and second half of infancy. However, children prefer ready-made food including biscuits (14.3%), soft drinks (25.4%), and chips (12.3%), juice (9.4%), cakes (5.8%), and other sweets (8.6%). This indicates to shift from traditional food types to read made ones among urban households. The majority of children (63.8%) take three meals a day, 21.9% take four meals a day, 2.9% take more four meals a day, and 11.6% take two meals a day. Mothers distribute child meal within a day giving a greater number of meals, but might be equal in amount of food given to a child. The majority of households depend on fathers (63.8%) for food provisioning for their children, while some other households (10.1%) depend on mothers, or relatives (26.1%). Household's members share the same dish (84.8%), or eat separately (15.2%).

Table 6 depicts average daily consumption of energy, protein, iron, vitamin A among anemic children and those suffering night blindness. From the table, children aged less than one year old consume more energy compared to other two groups 1-3-, and 4–6-year-old. Taking two age groups together had identified age groups -1-year-old + 4–6-year-old first and the two age groups -1 + 1- 3-year-old second, with very slight difference between them. The general average of the three age groups reveals low energy (calories) among children aged less than five-year-old in Khartoum State. Taking daily protein intake by age group of these children, distinguishes children aged less than 1 year old firstly, 4–6-year-old secondly and 1- 3-year-old lastly. Taking two age groups together ranked children aged -1-year-old + 4–6-year-old first with very slight difference between them, and those aged -1 + 1- 3-year-old second, and children aged 1-3 + 4-6 lastly. The general average of the three age groups reveals low protein among children aged less than five-year-old in Khartoum State. Ranking daily intake of iron by age groups of these children puts children aged -1-year-old first, 4-6 year second and 1–3-year-old last. There is slight difference in daily iron intake when two age groups of children are taken together. This is particular to the age groups -1 + 1- 3 and 1-3 + 4–6-year-old. The general average of daily iron intake depicts very low level among these children. This picture is also seen when daily intake of Vitamin A is taken into consideration.

Average daily intake of energy, protein, iron, vitamin A by age among children suffering anemia and night blindness distinguishes children aged less than one year most advantageous compared to the other two groups, and the general average of each of these nutrients is far below the recommended level for children to be healthy.

Table 6: average daily consumption of energy, protein, iron, vitamin A by age among children suffering anemia and night blindness

Age groups	No.	Energy (calorie)	Protein (g)	Iron (milligram)	Vitamin A (microgram)
- 1	50	11277.7	326.5	53.6	1239.7
1-3	153	8542.3	248.7	40.0	858.0
4-6	106	9756.6	279.4	45.7	979.7
-1 + 1- 3	66	5476.0	155.5	25.7	534.4
-1 + 4-6	74	5484.3	159.7	26.5	638.9
1-3 + 4-6	176	4900.6	140.0	22.7	462.8
-1 + 1-3 +4-6	76	3715.4	106.7	17.5	366.4

Table 7 depicts average hemoglobin measurement by age groups of children by daily intake of animal and plant protein. Highest measurement of hemoglobin among children aged less than one year old is coincided with highest levels of protein intake. This is similarly seen among children aged 4–6-year-old. Taking two age groups together ranks -1 + 4–6-year-old children first, and less tan1 years old + 1–3-year-old children second with very small non-significant difference. Increasing hemoglobin is coincided with increasing protein, confirming for nutritional status of these children. However, the general average of hemoglobin and both types of protein are far below the recommended levels for children to be healthy.

Table 7: average hemoglobin measurement (%) and daily intake of animal and plant protein among children suffering anemia and night blindness by age groups

Age groups	No.	hemoglobin	Animal protein	Plant protein
- 1	50	39.57	111.40	215.20
1-3	153	31.60	93.85	154.90
4-6	106	33.65	98.29	181.10
-1 + 1- 3	66	19.00	48.69	106.90
-1 + 4-6	74	19.13	52.41	107.40
1-3 + 4-6	176	16.62	49.27	90.74
-1 + 1-3 +4-6	76	12.40	33.81	72.92

The investigation of nutritional status of children suffering anemia and night blindness in Khartoum State suggests low hemoglobin rate, retarding food intake and malnutrition with differences by age groups and sex where males suffer more than females. The high rate of hemoglobin among children less than 1 year old might be attributed to more nutritional privilege and care given to a lactating mother. Sudanese culture supports neonatal period and early childhood where relatives can help with nutritional food types such as sweet porridge. Children become sick with night blindness starts between second and fifth year of a childhood, with more emphasis to males than females (American Journal of Nutrition, 2000). This contrasts susceptibility to Anemia susceptibility increases between 6 to 8 months of a childhood, but with more emphasis to males than females (Hassan et al., 2002).

Prevalence of low weight and malnutrition among children less than 5 years old in Khartoum State (Table 2) is almost similar to the 50 % cited by FAO and WFP for pre-2001 studies for Khartoum state [5]. However, it was higher than the most recent report Sudan household health survey of 42.9% (35.0% moderate and 7.9% severe) for Khartoum state [30]. The result was also higher than all previous studies carried out in Sudan, although it is similar to that by Al Jaloudi for children less than five years old living in poor urban Khartoum state [31]. In addition, the difference in malnutrition is possibly due to geographic reasons. In Khartoum State, squatter areas have expanded in recent decades which occupy the poorest people who generally face many healthy problems, such as lack of adequate food for their occupants (Alredaisy and Davies, 2003, Babiker and Alredaisy, 1997), where 70 to 80% of urban population live below the poverty line (Hamid, 2000).

Prevalence of breast feeding in the study area is attributed to the awareness of mothers to its nutritional value of to a newborn child, and to the inherited culture concerning breast feeding where Islam enhances mothers to breast feed their children for two years. It might be also related to that many urban households are not affordable to purchase ready-made food for their children, and also many of the mothers are housewives who are mainly devoted to child bearing. However, this is supported by the fact that, during pregnancy and lactation, mothers used to consume vegetables, fruits, milk, cereals, meat, and legumes abundantly compared to less amounts of these food types during lactation.

Comparing macronutrients daily intake in the study area with the study (Table 6) by Ministry of Agriculture and Forestry of Sudan [28] puts the study area below by that there are less protein, carbohydrates and lower energy intakes (1803 kcal vs. 1962 kcal) and above as there is fatter intake. They are less animal protein; vitamins, minerals consumed and abundant cereal are consumed. In the study area, fat and carbohydrates (calories) consumed were lower than the recommended values [27]. Energy obtained by higher protein and carbohydrates intakes was more than double the value obtainedby excess fat intake in this study [28]. Cereals highly contribute to energy and protein intake in the study area, a situation similar to rural Philippines where 361g/person/day are consumed there [29]. Animal protein sources such as meat and milk provide less than the recommended value which is 55.3g [28].

They are less than the recommended values for population in Africa which is 2041.7 calories (Latham, 1997)

The general conclusions of this study are as follows:

1- Children less than five-year-old suffering anemia and night blindness have retarding nutritional status.

2- Malnutrition and underweight are prevalent among these children.

3- Promotion of community and child nutrition is a necessity in the study area.

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9

Rural-urban profile of the nutritional status of children less than ten-years- old suffering anemia and night blindness in urban Khartoum state

9

Rural-urban profile of the nutritional status of children less than ten-years- old suffering anemia and night blindness in urban Khartoum state[(3)]

Although Sudan is rich in natural and human resources, 77.5% of the households surveyed in north Sudan were on or below the poverty line (MoL/ILO, 1997). The UNDP (2005) reported 75% of north Sudan population as poor. The majority (80%) is concentrating in rural areas where 30% of them suffered from extreme poverty. However, malnutrition is a real health problem in the country. Nutrition security strongly connected with food security, and is achieved at the household level when its members' food intake provides the recommended levels of protein, vitamins, minerals and energy. Food security is "a situation exists when all people at all times have sufficient access to sufficiently safe and nutritious for a healthy and active life" (FAO, 1996). Food insecurity is "a limited or uncertain access to foods of sufficient quality or quantity to sustain a healthy and active life" (Mohamed et al., 2004). Moreover, Thomas et al. (1997) differentiated between chronic and transitory food insecurity. The first type occurs when individuals or groups suffer from food insecurity at all times. The second type associates with a temporary decline in access to food due to temporary adverse circumstances. Transitory food insecurity was further divided into temporary and seasonal types. The first one is unpredictable, e.g., drought, unemployment. The second one usually follows a regular pattern of inadequate accessibility to food, i.e., agricultural season. Food insecurity can be related to fluctuation of production and price affecting the food or non-food sector leading to fluctuations in real income producer within the community (Valdes et al., 1981). Natural disasters,

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armed conflicts and hunger are also responsible for food insecurity (Alexander, 1997; Young, et al 2001; Hinrichs, 2002).

Nutrition insecurity leads to protein – energy malnutrition. Nutrition status is measured directly by dietary surveys, biochemical data, and anthropometric and clinical examination methods. Food adequacy is necessary for a household to achieve nutrition security, but it is not in itself sufficient. This is because some other key contributors to good nutrition are also important, such as poverty reduction, female education and a healthy environment. Nutrition deficiency diseases are worldwide spreading. In Sudan, one child out of ten dies before completing five years due to these diseases (UNICEF, 2008). Malnutrition due to micro nutrients deficiency (hidden hunger) represents the most prevailing form of nutrition deficiency diseases where more than two billion are suffering from it in the world; in addition to more than 250,000 children are affected by night blindness every year and more than half dies approximately (UNICEF, 2008). In Sudan, the estimated rate of prevalence of hidden hunger is 4.8% while the rate of anemia (iron deficiency anemia) for children less than five years old is about 55.1% (National Ministry of Health, 2008; World Health Organization, 2009). In Khartoum State, anemia due to Iron deficiency is distributed as 76% in Khartoum town, 75.3% in Khartoum north town, and 23.9% in Omdurman town (National Ministry of Health, 2008; World Health Organization, 2009). However, nutritional deficiency diseases as causes of death during early childhood, have contributed by around 51% among overall causes of death during this period (UNICEF, 2008).

Areas nutritionally insecure in Sudan include rural areas of low crop and animal production; areas of low purchasing power and education and knowledge; and areas of low access to health facilities, in addition to areas with low access to water especially during dry season (Cambrez et al., 1998; FAO/WFP, 2006). However, some researchers view poverty as the main cause of malnutrition while some others believe in malnutrition eradication without reduction in poverty pointing to well-nourished children living in very poor households. Female education is positively correlated with reduction in infant mortality rate (UNICEF 1990; Devads, 1980; Bhuiya et al.; 1986, Brahman 1988). Environment health largely determines nutritional status either through infections, depletion of nutrients and illness or vice versa. (UNU, 1979; Osmani, 1997; Biesel 1984).

Field Survey in Rural Western Kordofan:

Data was collected during August – October 2005. The villages were selected randomly and included Abu Serour; Rahad el Selik; Wad Gudiem; Um el Badri; el Karanik and Maryoud (Figure 1). The area was chosen due to its fragile environment with expected food problems. Population number is 92368 persons distributed in 14512 households. Cluster sampling is used for selection of rural villages by using probability proportional to size (PPS), and also used for the selection of the households from the ever-selected villages. The sample size was calculated by the formula:

$n = t^2\ pq/d^2 \times deff.$

Where:

n is the sample size,

t = 1.96,

q= 0.50,

p=0.05,

d =0.08

Deff. =1.5 (design effect).

Therefore: $n = (1.96)^2\ x0.05x0.50/\ (0.08)^2\ x1.5=225$

Clusters = sample size/desired number of households in a cluster = 225/20= 11.25 (all clusters).

Since there are 92368 persons distributed in 14512 households, this gives 25431 households.

Then rural clusters= 14512/11.25/25431=ca.6. So rural households included = 20x6=120To determine the share of each Hospital from this sample size, the equation of distribution in proportion to size of population (children suffering nutritional deficiency diseases) in each hospital is used, as follows:

$$n = \frac{Z^2Pq}{d^2}$$

n = sample size; Z = 1.96; P = prevalence rate of nutritional deficiency diseases; q = 1 – P; d = 0.05

The 10% prevalence rate of nutritional deficiency diseases in Khartoum State is used to get q which gave 138 individuals, as follows:

$$n = \frac{(1.96)^2 \times (1-0.1)}{(0.05)^2}$$

$$n = \frac{3.8416\times(0.9)}{(0.05)^2} = \frac{3.8416 \times 0.9}{0.0025} = 138$$

To determine the share of each Hospital from this sample size, the equation of distribution in proportion to size of population (children suffering nutritional deficiency diseases) in each hospital is used, as follows:

Cases of malnutrition in Khartoum (15628 = $\frac{100 \times 15628}{49003}$ =32

Cases of malnutrition in Khartoum north (12602) = $\frac{100 \times 12602}{49003}$ = 26%

Cases of malnutrition in Omdurman (20773) = $\frac{100 \times 20773}{49003}$ = 42%

The total cases of malnutrition in Khartoum State = 49003

The share of each town (hospital) of the sample size is determined as:

Khartoum = $\frac{138 \times 32}{100}$ = 44

Khartoum north = $\frac{138 \times 26}{100}$ = 36

Omdurman = $\frac{138 \times 42}{100}$ =58

The study covered dietary and anthropometric assessments of children less than 10 years old. Dietary assessments determined individual and household food consumptions. Anthropometric assessments involved physical measurements of the body such as weight, height, etc. Therefore, there are weight/height, weight for age, height for age and weight for height data, in addition to their sub-classifications (WHO 1995, Waterlow et al., 1977). Underweight, wasting, and stunting, in addition to measuring food frequency as consumption patterns during a week, were used to assess the nutritional status of children less than 10 years in the study area. Underweight is a measure of wasting or stunting or both. Weight measurements, which were taken to the nearest 0.1 kg, were taken by electronic scale. Subjects were weighted barefooted wearing minimum clothing. Salter scale was used for children less than two years old who are unable to stand. Height of children less than 2 years old was measured while they are lying on their backs with stretched legs and heads up. A wooden scale is used for children whose ages were 2 to less than 10 years old. Evaluation of nutritional status for children less than 10 years old was done by Z- score for the parameters of underweight (weight/age); wasting (weight/height); and stunting (height/ age). The criteria used is normal (≥I SA) and undernourished (≤I SA). The (≤ - I SA) criterion is further divided into mild (-1 to – 2 SD); moderate (12 to -1 SD) and severe (≥ -3 SD).

Measuring food frequency as consumption patterns during a week was recorded as consumption/day; every other day; twice/week; one/week; rarely or none. Household food intake (the 24-hour recall) was recorded in domestic measures and converted to weights. Nutrients intake was calculated using food consumption tables (Sukkar 1985, Boutros 1986). Individual food intake is calculated as an average per individual since all family members eat together, and it was evaluated as energy and protein intake.

Recommended allowance "RDA" calculation is based on FAO (1994[B]) RDA, and the figure for protein intake based on high fiber diet was applied since it represents the dietary pattern of the subjects covered by the study. An average figure was calculated from the RDA of household members above five years old to obtain the RDA per household for energy and protein. Adequacy intake based on households' RDA was calculated by: adequate ≥ 80% and inadequate ≤ 80%.

Field Survey in Khartoum State:

The fieldwork took place during February 2009 through to February 2010 in central specialized children hospitals in each of the three towns, including Ga'far Bin Oaf Hospital in Khartoum, Child Emergency Outpatient of Omdurman Hospital, and Ahmad Grasim Hospital in Khartoum north. A questionnaire was designed to collect relevant nutritional data of children suffering anemia and night blindness, as well clinical data on symptoms of anemia and night blindness. To estimate the sample size, based on that rate of prevalence of nutritional deficiency diseases in Khartoum State which is 10% (Khartoum State, Ministry of Health 2009), the following formula is used:

n = sample size; Z = 1.96; P = prevalence rate of nutritional deficiency diseases; q = 1 – P; d = 0.05

The 10% prevalence rate of nutritional deficiency diseases in Khartoum State is used to get q which gave 138 individuals.

Before conducting the fieldwork, anemia and night blindness were determined by testing blood samples of the sick children which is executed by Technicians working in each of the three hospitals, and by one of the authors. In addition, files of sick children were used. Symptoms of anemia and night blindness were specified by doctors during their routine rounds in the hospital. Following that, the questionnaires were filled with mothers of the sick children whom were chosen purposively. Hemoglobin measurement was done by Colorimeter, by taking 20 micro millimeters of the blood of the 138 sick children in a test tube, and 4 milliliter of Drabakin was added with 14.8 15 gram/deciliter concentration and fully mixed, left for five minutes to be read by Colorimeter. This gave that: Hemoglobin gm/Deciliter X 6.8 (constant factor) = Hemoglobin %Anthropometric measurements are done using Salter's scale to measure weight versus age for all the 138 children to determine their nutritional status. The nutritional status index of weight versus age is a quick and accurate method to determine the nutritional status of children less than five-year-old.

The evaluation of the nutritional status of children less than five-year-old was done using tables of estimation of rate for children less than five-year-old which is published by World Health Organization. The most indexes used to measure body to estimate nutritional status is weight for age index. Taking the measurement of weight is easier compared to measuring height and enable for more precision. Therefore, this measure is used into observing gradual growth in body volume and organs and helps into detection of early malnutrition.

Food weight measurement was also done which weights for 3 kilograms (electronic scale) to measure the amount of food consumed during the day. To determine average of energy, protein, iron and Vitamin consumed relative to the size of the household, children under study were divided into age groups including less than one year, 1-3 years, and 4-6 years; and -1 year + 1-3 years, -1 year + 4-6 years, (1-3) +(4-6) years and another age group including all age classes of 1 year + (1-3) + (4-6) years. This classification facilitates comparison between food consumption according to age groups of children less than five-year-old. Nutrients intake was calculated using food composition tables for population in Sudan, provided by Sukar (1985). Conditions for rejection included all children transferred from other States of Sudan hospitals during fieldwork, and the study has restricted to those who live permanently in Khartoum State during the time of fieldwork. The data was statistically analyzed to calculate frequencies, percentages and Chi – square test.

The Study Areas:

Rural western Kordofan (figure 1) has a semi-arid environment with climatic fluctuations and average annual rainfall of 200 mm. Sand dunes and sandy soils are dominant and natural vegetation is sparsely. Children less than 10 years constituted 36.5% of the total population distributed as 17.8% males and 18.7% females. Average household size of 4-6 person included 50.8% of total households surveyed, while 7-10 person households represented 36.7%. Male headed households represented 44.1% of total households. Illiteracy is high by 75.9% among households surveyed, who are mainly peasants. They cultivate sorghum (Dura) and bulrush millet (Dukhn), sesame and groundnuts. Monthly income is distributed as 59.2% earns less than 200 SDG, 30.0% earns 200-300 SDG. They generally fall below poverty line as their incomes are far less than one USD per day. The so-called higher income groups (301-500 and ≥ 500 SDG) totaled 10.8%.

Khartoum States consists of the three towns of Khartoum, Khartoum north and Omdurman (Fig.1). Rate of population increase in Greater Khartoum was 4.92 in 1956, 7.76 in 1973, 8.75 in 1983, and 13.7 in 1993 (MFEP 1956–1993). The number of persons per square kilometer was 55.6 persons in 1973, 85.5 in 1983 and 169 in 1993. In addition, Khartoum state accepted 39% of internal migration of the country in 1983 and 45% in 1993 (MFEP 1956 – 1993). This population increase is reflected in the expansion of informal squatter areas (El Bushra, 1995) and consequently higher demand for public services.

Figure 1. Location of rural western Kordofan and Khartoum State

Dietary Evaluation:

Rural western Kordofan:

In rural western Kordofan, the average contributions of carbohydrates, protein and fat to total energy were 56.2%, 9.3%, and 34.5% respectively (table 1). Less meat was consumed here but, the higher fat figure was due to consumption of more groundnuts and groundnuts oil as it is produced, pressed and refined locally. Cereals highly contribute to energy and protein intake in the study area. Frequency of daily cereals' product consumption was higher for sorghum porridge "Asida", which provides less energy due to its high moisture content. This seems the only viable explanation for higher cereal products in rural households but there is less energy and protein intake. Cereals products provided 42.7% of total energy and 45.2% of total protein (table 1). Here, meat is consumed by 70.5% of the surveyed households. Moreover, nutritional adequacy can be roughly assessed from energy and protein content of the daily diet relative to the recommended allowances (RDA). Inadequate energy intake means that the quantity of food consumed was below optimum need as the energy value is derived from all three macronutrients. The rural households of the study area consume diets low in quantity and intermediate in protein quality as the major source was plant protein which produced locally.

Table 1. Parameters of Nutrients' contribution (%) to total energy intake & recommended range (R); Macronutrients' mean daily intake and Cereals contribution to total energy (kcal) and protein (g) intake in the study area

(1) Nutrients' contribution (%) to total energy intake & recommended range (R)		
Carbohydrates	56.2	R= 55-60
Protein	9.3	R= 10-15
Fats	34,5	R= 25-30
(2) Macronutrients' mean daily intake		
Energy (kcal)	1663±383*	1803±449
Protein (g)	37.7±11*	42.0±14
Carbohydrates (g)	232.6±70*	261.4±80
Fat (g)	63.5±23**	64.5±25
Animal protein (g)	9.8±4.6*	13.1±6.3
Animal fat (g)	7.5±9*	12.2±11
(3) Cereals contribution to total energy (kcal) and protein (g) intake		
Energy	774.7±163*	824.3±172
% of total energy	46.5	45.7
Protein	16.1±3.9**	19.0±6.8
% of total energy	42.7	45.2

Source: Fieldwork (2005)

Khartoum state:

The majority of the mothers (61.6%) perceive that breast feeding is important and prevents childhood diseases, while some others (38.4%) ignore that. However, 97.1% of the mothers used to breast feed their sick children after three days following their delivery. The average period of breast feeding is eleven months. Mothers who did not breast feed their children; have attributed that to death of a mother (25%), infection of mother with tuberculosis or psychiatric diseases (50%), or the child being sick (25%). During the early 2 months of a new born baby, 89.9% of the mothers used to breast feed their children and give supplementary food, while few mothers (7.2%) depend solely on breast feeding, and still very few mothers (2.9%) wholly depend on supplementary food. During the second half of the first year of a child (6 - 12 months), very few mothers (0.41%) depend on breast feeding as the main source of feeding their children, while 87.7% of them combine breast feeding with supplementary food, and 10.9% give their children supplementary food only. This means that, the majority of mothers did not change their behavioral pattern of child feeding throughout the first year of a child life. However, children prefer biscuits (14.3%), soft drinks (25.4%), and chips (12.3%), juice (9.4%), cakes (5.8%), and sweets (8.6%) as supplementary food types. The majority of children (63.8%) take three meals a day, 21.9% take four meals a day, 2.9% take more than four meals a day, and 11.6% take two meals a day. More numbers of meals do not necessarily mean more amounts of food given to a child as mothers have used to distribute a child meal within a day hours. The majority of the households' members shares the same dish (84.8%), or eats separately (15.2%).

Table 2 depicts average daily intake of energy, protein, iron, and vitamin A among children suffering anemia and night blindness. From the table, children aged less than one year old ranked first in energy intake compared to other two groups of 1-3-, and 4–6-year-old. Taking two age groups of children together, children aged -1-year-old + 4 - 6 year-old ranked first and followed respectively by those aged -1 + 1- 3 year, with very small difference between them. The general average intake of energy for the three age groups reveals low energy (calories) intake among children aged less than five-year-old in Khartoum State. Taking daily protein intake by age group of these sick children, children aged less than 1 year old ranked first, followed by 4–6-year-old, and lastly 1- 3 year-old. Taking two age groups together, had ranked children aged -1-year-old + 4-6 year-old first, and those aged -1 + 1- 3 year old second, while children aged 1-3 + 4-6 came lastly. The general average intake of protein for the three age groups reveals low protein intake among children aged less than five-year-old in Khartoum State. Moreover, ranking daily intake of iron by age groups of these sick children puts children aged -1-year-old first, 4-6 year second, and 1-3 year-old last. There is slight difference in daily iron intake when two age groups of children are taken together. This is more seen among children in the age groups of -1 + 1- 3 and 1-3 + 4–6-year-old. The general average of daily iron intake depicts very low level among these children. This picture is also seen when daily intake of Vitamin A is taken into consideration.

Average daily intake of energy, protein, iron, and vitamin A by age groups of children suffering anemia and night blindness had identified children aged less than one year as the most advantageous group compared to the other two groups. In addition, the general average of each of these nutrients is far below the recommended level for children to remain healthy in Arica and Sudan.

Table 2. Average daily intake of energy, protein, iron, vitamin A by age among children suffering anemia and night blindness

Age groups	No.	Energy (calorie)	Protein (g)	Iron (milligram)	Vitamin A (microgram)
- 1	50	11277.7	326.5	53.6	1239.7
1-3	153	8542.3	248.7	40.0	858.0
4-6	106	9756.6	279.4	45.7	979.7
-1 + 1- 3	66	5476.0	155.5	25.7	534.4
-1 + 4-6	74	5484.3	159.7	26.5	638.9
1-3 + 4-6	176	4900.6	140.0	22.7	462.8
-1 + 1-3 +4-6	76	3715.4	106.7	17.5	366.4

Physical symptoms of anemia are loss of appetite (87.7%), paleness (93.5%), exhaust, eating clay (29%) and snow (2.9%). The symptoms of night blindness are night blindness (12%); xerophthalmia(20%); Pinot spots (52%); karatomalacia (12%), and Cornea ulceration (4%). Hemoglobin measurement for children suffering night blindness (Table 3) revealed that children aged 1–3-year-old have less hemoglobin concentration compared to those aged less than one year and 3-5 years old who have equal concentration of hemoglobin. This means that children aged 1–3-year-old suffers Iron deficiency anemia compared to the two other two groups. This contrasts child suffering anemia, where children aged 1-3- and 3–5-year-old are almost have equal concentration of hemoglobin which exceeds that for children aged less than one year old who might differ significantly than the previous two age groups. This means that, children -1-year-old are more anemic compared to those aged 1-3-, and 3–5-year-old. The general striking feature of distribution of night blindness and anemia among these three age groups is that, each age group has acquired of incidence of a disease and the differences might be quite minor. The distribution of children suffering night blindness by sex by percent of hemoglobin concentration (Table 3) depicts males to have higher level than females, which is also applicable to anemia. However, the differences might not be significant. Children suffering anemia and night blindness distributed among different age groups have very low percent of

hemoglobin concentration below 60% standard (National Ministry of Health, 2004), confirming for prevalence of Iron deficiency anemia.

Table 3. Hemoglobin range measurement (%) among children suffering anemia and night blindness by age and by sex

Age / sex	Night blindness		Anemia	
	frequency	%	frequency	%
-1 year	3	37	31	32.2
1-3years	18	34.8	73	38.8
3-5 years	4	37	9	39.1
Males	60	43.5	15	10.9
Female	53	38.4	10	7.2
Total	113	81.9	25	18.1

Anthropometric Evaluations:

Rural western Kordofan:

Table (4) shows anthropometric evaluations for children less than ten years old in rural western Kordofan. Wasting prevalence was 37.9% (19.6% as moderate and 18.3% as severe). Wasting was prevalent in the study area (41.0%). Within each level of wasting, 74.4% is moderate, and 67.5% is severe. Since the survey was carried out during the pre- harvest season (August/October), a period of food scarcity in such rural areas, there will be less food intake and by so more incidence of wasting is expected as the index indicated to recent low food intake in addition to poverty. Stunting prevalence in the study area was 23.7% (12.3% moderate and 11.4% as severe). Underweight was prevalent by 54.1% and constituted the majority within the moderate (68.1%) and severe cases (81.8%). Wasting for all children was 55.9%, 32.2% moderate and 23.7% severe. Wasting was higher for children less than five years old at all the three levels especially severe wasting, which is probably an indication of even lower food intake at the fieldwork time. Wasting prevalence was higher (60.5%), and within these rural households, it was found to be higher within the moderate (67.6%) and the severe (74.0%) cases. Stunting prevalence was 11.4% (7.1% moderate and 4.3% severe). Generally, higher prevalence rates for moderate and severe stunting were recorded for these rural children.

Table 4. Nutritional status of children less than ten in rural western Kordofan

Parameter	Nutritional status	No.	%
Wt/age[a]	Normal	60	41.7
	Moderate	59	40.9
	Severe	25	17.4
P=0.194	**total**	144	100.0
Wt/height	Normal	85	59.0
	Moderate	32	22.2
	Severe	27	18.8
P=0.003	**total**	144	100.0
Height/age	Normal	100	69.4
	Moderate	20	13.9
	Severe	24	16.7
P=0.001	**total**	144	100.0
Wt/age[b]	Normal	63	45.9

	Moderate	47	34.3
	Severe	27	19.7
P=0.025	**total**	137	99.9
Wt/height[b]	Normal	54	39.5
	Moderate	46	33.5
	Severe	37	27.0
P=0.064	**total**	137	100.0
Height/age	Normal	118	86.1
	Moderate	12	8.7
	Severe	7	5.1
P=0.121	**total**	137	99.9

A=≤ 5, b= ≤ 10 , Source: Fieldwork (2005)

Khartoum state:

Table 5 depicts state of malnutrition as indicative by weight of children. Severe malnutrition was the most prevalent type of malnutrition with significant difference than the other three types of malnutrition shown in table 5. The difference between normal and simple types of malnutrition is quite small. Severe malnutrition is a reflection of low nutritional status which makes children vulnerable to childhood diseases. The distribution of rate of malnutrition by age groups of these children suffering anemia and night blindness (Table 6), identified the highest rate of malnutrition among children aged 1–3-year-old, then followed by children aged less than one year old and lastly by those aged 3–5-year-old. This means that severe malnutrition remarkably prevails among children aged 1–3-year-old, which significantly differs than the other two age groups. Furthermore, the difference between children aged -1-year-old and children aged 3–5-year-old is more than doubled. The distribution of malnutrition by sex by age depicted that males are more suffering than female, but both males and females aged 1-3 year, are the most suffering than the other age groups. However, females are generally less malnourished than males with a percent difference of 8.6 between them (Table 6).

Table 5. malnutrition indicated by weight of children less than 5 year old in Khartoum State

Malnutrition state	frequency	%
Normal	11	8.0
simple	13	9.4
Medium	27	19.6
Severe	87	63.0
total	138	100.0

Table 6. Malnutrition by sex by age

Age	Sex				Total	
	Males		Females		Frequency	%
	frequency	%	frequency	%		
-1 year	18	13	16	11.6	34	24.6
1-3years	47	34.1	43	31.2	90	65.3
3-5 years	10	7.2	4	2.9	14	10.1
total	75	54.3	63	45.7	138	100

Factors Influencing Nutritional Status of Children Rural western Kordofan:

In these rural households, energy and protein intakes also increased with increasing income. The level of significance was lower for energy, probability 0.042, and was significant for protein with probability of 0.053. Comparison between lowest income group and highest one depicts an increase by 34.6% in energy and 41.3% in protein. Higher income groups (301-500 and ≥ 500 SDG) totaled 10.8%. By that way, 89.2% of the rural household did not benefit from increasing income that lead to increasing intake of energy and protein. Increased food expenditure had significantly increased energy and protein intakes in the study area for both energy, probability of 0.042, and for protein with probability of 0.025. In the later case, such an increase is not as important as that for those whose food expenditure amounted to ≥ 100 SDG, who constitutes 9.1% of the households, while for the remaining 90.9% there was practically no increase.

A significant relationship exists between food expenditure and under-nutrition prevalence in the study area with probability of 0.004. This commensurate with the fact that food expenditure positively affected energy and protein intake and thus the energy status of the body. As far as number of meals per day is concerned, it is expected that more energy and protein will positively correlate with three meals per day other than with two meals. Meals provided more energy was not detected in these rural villages where the probability was 0.104. Increase in protein intake was not significant for these rural households where the calculated probability was 0.145. The noticeable increase in energy here can be attributed to poverty, where 95.8% of the households earned ≤ 5 US$/ day (table 7). Number of meals per day influences energy and protein intakes, a positive relationship confirmed in the study area by a probability of 0.006.

Energy intake reversibly decreased with increasing household size, where the calculated probability was 0.042 (table 7). The decrease in kcal was slightly low here (17.3%). Protein intake also decreased with increasing household size; probability was 0.000. Decrease in protein was high in these poor rural areas (26.7%) as they had big families. These factors point out to decreasing protein intake with increasing number of persons sharing the common dish which its protein content was originally low. Positive relationship exists between household size and nutrition status in these rural areas and the calculated probability was 0.018. Since energy and protein intakes were less and the households are big enough, it is expected to have positive relationship between household size and nutrition status.

Table 7. Factors determining the nutritional status of children less than 10 years old in rural western Kordofan

parameters	Rural	
	No.	%
1- **Income** (SDG)		
≤200	71	59.2
200-300	36	30.0
301-500	10	8.3
≥ 500	3	2.5
Total (P=0.000), P means probability	120	100.0
2- **Food expenditure** (SDG) / day P= 0.000		
≤ 5	29	24.2
5- ≤ 10	80	66.7

10- ≤ 15	10	8.3
≥ 15	1	0.8
total	120	100.0
3- Number of meals/day P= 0.000		
Two	96	80.0
Three	24	20.0
total	120	100.0
4- Household size P= 0.223		
1-3	8	6.7
4-6	61	50.8
7-10	44	36.7
≥ 10	7	5,8
total	120	100.0
Poverty classification US$/ day		
≤ 5	115	95.8
5 - ≤ 10	-	-
10 - ≤ 15	5	4.2
≥ 15	120	100

Source: Fieldwork (2005)

Table 8 depicts highly significant probability confirming the relationship between household monthly income and number of meals a child takes per day. This implies increased food expenditure and higher level of energy; protein; iron; and vitamin intake, as well as consumption of better-quality protein, with increasing income. Less income will of course result in prevalence of anemia and night blindness in the study area. However, the relationship between nutritional status of children suffering anemia and night blindness and type of food of a mother during pregnancy gave highly significant probability (Table 8). The food types during pregnancy (table 4) reflect household monthly income level, educational attainment, and other socioeconomic characteristics of the surveyed households in the study area. The relationship between sex – age structure of children suffering anemia and night blindness and frequency of daily intake of bread and cereals (P = 0.0008), milk and milk products (P= 0.0008); legumes (P = 0.0007); vegetables (P = 0.0001); fruits (P = 0.0005); and other food types (p =0.0004);

are positive and highly statistically significant which suggests for influence of food nutrients on anemia and night blindness during early childhood. There is highly significant relationship between nutritional status of children suffering anemia and night blindness and number of children under five-year-old in the household (P= 0.0002). This points out to decreasing food nutrients intake with increasing number of persons sharing the common dish which its protein content was originally low. This is further depicted by the relationship between nutritional status of these sick children and ideal method for food distribution in the family (P = 0.027). Since energy and protein intakes (Table 6) were less and the households are big enough, it is expected to have positive relationship between household size and nutrition status of these sick children. In addition, relationship between hemoglobin level (%) and amounts of animal protein consumed is positively statistically significant (P= 0.01); and similarly with plant protein (P= 0.03).

Table 8. Chi-Square test for relation between some socioeconomic factors and nutritional status of children suffering anemia and night blindness in Khartoum State

Parameters	Probability
Monthly income and number of meals per day by child Monthly income (-300; 300-750; 750+) Number of meals (-2;3;4; 4+)	0.002
Nutritional status and type of food during pregnancy Nutritional status (normal; simple; moderate; Severe) Type of food during pregnancy (see table 4)	0.0056
Age-sex structure of children – 5 year old and frequency of bread and cereals intake / day Age –sex structure (see table 3) Frequency of bread and cereals (daily, once a week; twice a week; trice a week)	0.00080
Age-sex structure of children – 5 year old and frequency of milk and milk products intake / day Age –sex structure (see table 3) Frequency of milk intake (daily, once a week; twice a week; trice a week)	0.0008
Age-sex structure of children – 5 year old and frequency of meat and meat products consumed / day Age – sex structure (see table 3) Frequency of meat and meat products intake (daily, once a week; twice a week; trice a week)	0.0003
Age-sex structure of children – 5 year old and frequency of legumes intake / day Age – sex structure (see table 3) Frequency of legumes intake (daily, once a week; twice a week; trice a week)	0.0007
Age-sex structure of children – 5 year old and frequency of vegetables consumed / day Age – sex structure (see table 3) Frequency of vegetables intake (daily, once a week; twice a week; trice a week)	0.0001
Age-sex structure of children – 5 year old and frequency of fruits consumed / day Age – sex structure (see table 3) Frequency of fruits intake (daily, once a week; twice a week; trice a week)	0.0005
Age-sex structure of children – 5 year old and frequency of other food types (dates, Karkadh, Gongolaiz) consumed / day Age – sex structure (see table 3) Frequency of other food types intake (daily, once a week; twice a week; trice a week)	0.0004
Nutritional status and number of children under five year old living with family and outside family Nutritional status (normal; simple; moderate; Severe) Children under 5 year old (living with the family; outside the family)	0.0002
Hemoglobin and amounts of animal protein consumed Hemoglobin (see table 1) Animal protein (see tables 6 and 7)	0.01
Hemoglobin and amounts of plant protein consumed Hemoglobin (see table 1) Plant protein (see tables 6 and 7)	0.03
Nutritional status and ideal method for food distribution in the family Nutritional status (normal; simple; moderate; Severe) Ideal method of food distribution (sharing one dish, separately)	0.027

Discussion:

The study investigated nutritional status of children less than ten-year-old in a rural and an urban geographic setting of Sudan. In rural western Kordofan, daily intake of protein, carbohydrates and energy for children less than ten-year-old is below FSU (2005) results (1803 kcal vs. 1962 kcal). Energy obtained by higher protein and carbohydrates intakes by FSU study was more than double the value obtained by excess fat intake in rural western Kordofan. Cereals highly contribute to energy and protein intake in rural western Kordofan, a situation similar to rural Philippines where 361g/person/day are consumed there (Florentino, 1999). The investigation of nutritional status of children suffering anemia and night blindness in Khartoum State suggests low hemoglobin rate; inadequate food intake and prevalence of malnutrition by age and sex with major and minor differences. Males suffering anemia and night blindness are more malnourished compared to females. This agrees with the fact that, generally children suffer night blindness between second and fifth year of childhood, with more emphasis to males than females, but the situation is different concerning anemia which prevails more between 6 to 8 months of a childhood, but with more emphasis to males than females (Hassan et al., 2002). Comparing macronutrients daily intake in Khartoum State with the study by Ministry of Agriculture and Forestry of Sudan (FSU, 2005) puts the study area below by that there are less protein, carbohydrates and lower energy intakes. There is less animal protein; vitamins, minerals consumed and abundant cereal are consumed. In the study area, fat and carbohydrates (calories) consumed were lower than the recommended values (Katch, 1983) and for population in Africa which is 2041.7 calories (Latham, 1997). This study agrees with Mohammed's study in Al Shigla area in east Khartoum State, which indicated to imbalanced intake of food types where legumes and cereals are abundantly consumed while meat, fish and chickens are less consumed among surveyed households (Mohamed, 1999). It also agrees with Ali's study in north state of Sudan where cereals are the main source for poor households although cereals are deficient in vitamin A, and 41% of the sample suffers vitamin A deficiency (Ali, 2005). Energy obtained by higher protein and carbohydrates intakes was more than double the value obtained by excess fat intake in this study (FSU, 2005).

Prevalence of breast feeding in Khartoum State is attributed to the awareness of mothers to its nutritional value to a newborn child, and to the inherited Islamic culture which enhances mothers to breast feed their children for two complete years. It might be also attributed to that, the majority of urban households are incapable to purchase readymade food for their children where 70 to 80% of urban population live below the poverty line (Hamid, 2000), and also many of the mothers are mainly housewives who have fully devoted themselves to child bearing. The low rate of hemoglobin concentration among children suffering anemia and night blindness is below 60% standard rate, and confirms prevalence of Iron deficiency anemia. This might be attributed to illiteracy of mothers and poverty and also to some food habits. Sudanese mothers used to give children tea directly after a meal. Tea contains Phenols components which reduces Iron absorption (Sudan National Ministry of Health, 2003).

In rural western Kordofan, underweight children represented 58.3% here, which is almost similar to the 50.0% cited by FAO/WFP (2006) for pre-2001 studies for north Kordofan state. However, it was higher than the most recent report (SHHA, 2006) of 42.9% (35.0% moderate and 7.9% severe) for north Kordofan state. The result was also higher than all previous studies carried out in Sudan, although it is similar to that of Al Jaloudi (2000) for children less than five years old living in poor urban Khartoum state. Yet, severe under nutrition was reported higher in west Kordofan than in north Kordofan (MICS, 2000). Wasting prevalence was 37.9% (19.6% as moderate and 18.3% as severe) while in the SHHS (2006) for north Kordofan state it was lower (16.0% total: 13.5% moderate and 2.5% severe). Figures obtained in this study were also higher than those obtained previously by Al Jaloudi (2000) which were, 18.7% moderate and 2.2% severe. In all relevant studies severe wasting was ≤ 3% but, however our study shows higher level. A stunting as measure of chronic undernutrition prevails in the study area as it was 23.7% (12.3% moderate and 11.4% as severe) which was lower than all previous studies for total or severe cases, which were 51.0% for north Kordofan and 47.7% for whole the Sudan (SHHA,2006). It was even lower than the figure of Sub-Saharan Africa of 38.0% (UNICE, 2008), or the 55.9% for rural Ethiopia (Yousuf, 2000). However, one in every seven children was wasted and one in every three was stunted in north Sudan (SERISS, 1988). Prevalence of low weight and malnutrition among children less than 5 years old in Khartoum State is almost similar to the 50 % cited by FAO and WFP for pre-2001 studies for North Kordofan state (FAO/WFP, 2006). However, it was higher than the most recent report Sudan household health survey of 42.9% (SHHA, 2006). The result was also higher than all previous studies carried out in Sudan, although it is similar to that by Al Jaloudi for children less than five years old living in poor urban Khartoum state (Al Jaloudi, 2000). In addition, the difference in malnutrition is possibly due to geographic reasons. In Khartoum State, squatter areas have expanded rapidly in recent decades, occupied by poorest people who are generally facing inadequate food intake and unhygienic residential environment (Alredaisy and Davies, 2003, Babiker and Alredaisy, 1997).

Rural and urban communities in Sudan are generally suffering from lack of socioeconomic and community development projects, a situation further exacerbated in rural Sudan by adverse climatic conditions. The majority of rural population of Sudan lives in areas characterized by fragile environments and vulnerable to crop failure and animal loss. These situations determine the nutritional status of the population in general and children of less than 10 years old in particular who are mostly risky to malnutrition and infectious diseases. Environmental factors in rural western Kordofan somehow determine food production, food availability and population affordability to buy food. Rural western Kordofan is environmentally fragile. It lies within "very high risk" zone of desertification designated by the United Nations (UN 1977). Its average annual rainfall values decreased markedly since early sixties (El Gamri, et al., 2009). Natural vegetation has deteriorated and total biomass gets over-exploited by grazing and browsing animals (Davies 1987). Resident population of the study area used to increase their cultivation area since coefficient of variation of the annual rainfall is about 30% the area cultivated and the productivity varies widely from one year to another (MOIWR 1999), causing desertification (Iskander1989) and deterioration of the food system (Alredaisy & Davies 2001).

Fieldwork results in rural western Kordofan depicted higher level of protein intake that implies consumption of better-quality protein with increasing income. There is significant increase in energy and protein intakes with increasing incomes and a similar increase that was highly significant were recorded for protein (Ibrahim, 2008). This similar to the fieldwork results in Khartoum State which depicted positive relationship between numbers of meals a child takes per day and household monthly income. Some researchers are convinced that increasing income leads to increasing food intake (Strauss 1984, Maxwell et al 2000) while some others believe that poor households spend their additional incomes on more expensive foods such as finer cereals, meat or dairy products which do not necessarily yield more energy. The fieldwork results support the first assumption that increasing income had positively increased energy intake, and therefore increased protein intake. Income was also positively correlated, probability of 0.000, with the nutritional status. Less income resulted in prevalence of under-nutrition in rural western Kordofan. Thus decreasing income led to marginal or sub-optimal intakes of energy and protein resulting in more prevalence of under-nutrition. In addition, it is expected that more energy and protein will positively correlate with three meals per day other than with two meals.

The growth of towns and cities in Sudan has been accompanied by growing numbers of poor and vulnerable urban dwellers (Sara Pavanello, 2011). The majority of the urban poor are dependent upon marginal livelihood activities in the informal economy, and their access to safe and sustainable livelihoods is extremely unstable (Sara Pavanello, 2011). However, many studies in Sudan referred low weight, stunting and wasting among young children to unequal income distribution, vertically between incomes and horizontally between rural and urban areas (UNDP 2006), and to mothers' literacy which positively effects low weight- for- age compared to illiterate mothers who have more stunted children in Sudan (FAO/WFP, 2006). Many studies in Sudan referred low weight among young children to unequal income distribution, vertically between incomes and horizontally between rural and urban areas (UNDP 2006). Furthermore, increased income will increase food expenditure in the study area as has been confirmed in rural western Kordofan State (Alredaisy and Suleiman, 2011) that had significantly increased energy and protein intakes in the study area for both energy, probability of 0.042, and for protein with probability of 0.025, and significant relationship exists between food expenditure and under-nutrition prevalence in the study area with probability of 0.004.

The relationship between nutritional status of children and type of food consumed during pregnancy is highly significant (0.0056). This might be attributed to household monthly income, educational level of a mother or a father where the majority has attained religious or basic education. Mothers' literacy positively effects low weight- for- age compared to illiterate mothers who have more stunted children in Sudan (FAO/WFP, 2006), and in Khartoum State (Magboul et al, 2000) and SERISS (1988) and SMCH (1995) results where mothers' educational level was remarkably influential.

One of the main reasons for generally declining levels of food consumption in the study area is attributed mainly to the high living costs and high inflation rates in Sudan. The high expenditure on food in situations of low income, big households and illiteracy has many consequences. One consequence is that, a low-income household's consumer surplus for food is very high, amounting to a substantial proportion of its total income. This has important consequences for the economic appraisal of food supply. With regard to affordability, households are unable to pay for food at the current cost. High proportion would be unable to pay the actual costs of food. The revenue that may realistically be expected to be recovered from these households in the future lies somewhere between what they are able to pay and what they are presently willing to pay. Another consequence is the lack of elasticity and repercussions on expenditure for food would imperatively be retarded. The high price of food in urban Sudan is probably a major cause of the malnutrition prevalent in the squatter areas (Sandy et al, 1992). Decreasing income led to marginal or sub-optimal intakes of energy and protein resulting in more prevalence of under-nutrition in rural western Kordofan of Sudan (Alredaisy and Suleiman, 2010).

Conclusions:

The general findings of this study are as follows:

1. This study gave an example on nutritional problems in rural and urban Sudan.
2. General nutritional status of children less than ten-year-old in rural and urban settings is below the recommended level for individual to remain healthy.
3. Malnutrition, underweight, stunting, and wasting and are prevalent in rural and urban Sudan.
4. There are no significant differences between rural and urban children concerning their nutritional status

5. Poverty, illiteracy, big household size, and environmental factors operate in rural and urban Sudan to determine nutritional status of young children.

6. Promotion of community and child nutrition is a necessity in the study area.

Based on that, some suggestions could be presented. Firstly, breast feeding should be enhanced from delivery up to six months of a child age, and should be accompanied by supplementary feeding thereafter up to the completion of two years of a child age. Secondly, more care should be devoted to qualitative and quantitative complementary feeding. Thirdly, introduction of balance diets rich in vitamin A, and Iron when a child completes six months of age, and during pregnancy and lactation is a necessity. Fourthly, nutrition education should be introduced and enhanced among mothers to accept knowledge about good child feeding. Fifthly, rural urban poor should be supported by small – finance projects to curb financial inflation which adversely depriving this segment of the society. In addition, rural communities' improvement of community nutrition could include crop diversification to increase cash income among peasants; utilization of native food for child nutrition; benefit of seasonal food surplus by storage, combating desertification, reducing overgrazing and over wooding by introduction of solar energy and reclamation of forests, female education, health education and child spacing; developing youth capacity for social.

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Assessment of Environmental Health Conditions in Urban Squatters of Greater Khartoum, Mayo Area in the Southern Khartoum, Sudan: 1987–2011

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Assessment of Environmental Health Conditions in Urban Squatters of Greater Khartoum, Mayo Area in the Southern Khartoum, Sudan: 1987 – 2011(4)

Provisioning of good environmental health conditions is a challenge worldwide. Environmental health is defined by World Health Organization (1983) as “The ecological balance that exists between Man and his environment, in order to ensure his well-being. This well-being concerns the “whole Man”, not only his physical health, but also his mental health, and the optimum relations within his environment. In the same way, it concerns the “whole environment” from the individual human dwelling to the entire environment”. One of the main challenges to provisioning of good environmental health conditions is the growth of urban population. There are 3.3 billion of the world's population lives in urban areas (UNFPA, 2008). This represents 47% of the world’s population (Tajudeen 'et al' 2006), and it was predicted that by the year 2030 this number will reach five billion and 95% of this growth will take place in the developing countries. This rapid urban growth has led to the growth of informal settlements (Banker and Alredaisy, 1997). In the year 2003, nearly one sixth of the world’s total population lived in slums and this number is likely to be doubled in next 30 years (UN-Habitat, 2003). It was estimated that between 20 to 80% of urban settlements in developing countries are informal, and by the year 2030 the number of worldwide slum dwellers will reach two billion (ECOSOC, 2005). Although urban growth in sub-Saharan Africa’s is higher than the world’s average (Bocquier 2005), this region had experienced declining urban growth during 1990s and 2000s (Bocquier 2003; Bocquier and Traoré 2000). This suggests that migration has contributed even less to urban growth in the recent past in Africa (Potts 2006), where the events that take place in the life of an individual

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contribute greatly to his decision to migrate over the lifetime (Kulu and Milewski 2006). Squatter settlements are characterized by low-income groups of population as they receive rural migrants and intra-urban movements from other slum areas (Muindi et al. 2009), as well as being overcrowded and lack access to environmental health facilities (Ali et al., 2004).

Sudan urban development, vulnerability to rapid urban growth, squatter growth and physical or anthropogenic effects on squatter growth are more or less similar to those operating in Third World countries. Drought is a principal driver of urbanization in Sudan (Sara, 2011), similar to the Sahel region which has been spurred on by recurring drought and the threat of long-term land degradation (Seaquist et al. 2009, Mertz 2010). The fertility rate in Sudan was 5.9 births per woman in 1999; while annual population growth rate was 2.53 % between 2003 and 2007, and the natural rate of increase was 41.23 per 1 000 in 2006 (Ministry of Health, Sudan. 2008).

Greater Khartoum's degree of urban primacy has changed, whereas in 1955 Khartoum had 4.7 times the population of Sudan's second-largest urban center, by 1993 this had increased to 8.9 times (Davies 2001). Generally, growth of towns and cities in Sudan has been accompanied by growing numbers of poor and vulnerable urban dwellers (Sara, 2011). Housing as a primary demand, from whose scarcity much of the causes for squatter growth could be attributed. The high demand for housing in urban Sudan was ignited by low implementation of residential urban plans, and furthermore exacerbated by lack of knowing how to manage urban development and growth because of low funding, social disruptions such as renewing wars in southern Kordofan (western Sudan) and Blue Nile (southeastern Sudan), famine and drought, future uncertainty due to climate change and rapid population growth.

The urban areas in Sudan are managed through a hierarchical administrative system. It starts from the State Governor, and descend to Administrative Officer entitled to an administrative unit in a locality. In addition, People's Committees in residential areas were entitled to do some jobs such as follow up of garbage collection, but without an entitled financial budget. The allocated financialbudget for the administrative units at the national level does not commensurate with actual needs for expenditure on services. Therefore, these administrative units, however, completely depend on collecting direct taxes from individuals (either traders or houses' owners) to spend for services, which always in deficit. In addition, local governments consider squatter areas as illegal developments. Consequently, no budget was allocated for environmental health services, although water and electricity services might be provided. Waste disposal collection, for example, depends on direct monthly payment of residents by 2 $. Twice a week schedule for waste collection, although specified by administrative units, was not effectively executed. The other serviceswere provided to the minimum. Furthermore, Infrastructure development in urban Sudan does not commensurate with urban population growth and new residential developments. This is one of the major causes of the existing problems of environmental health conditions in urban Sudan, particularly the squatter areas. These might be due back to financial crisis, heavy burden of foreign indebt and civil wars in Sudan.

Many countries have tried to promote squatter settlements. In the mid-eighties, India introduced a slum redevelopment strategy in Bombay, involved the demolition of existing slums and the redevelopment of new, higher density, medium-rise apartment blocks, including, entirely cross-subsidized housing for the original slum dwellers (Vinit Mukhija 2002). Tanzania has recognized squatter settlements as part of the urban fabric, provided minimum level of services, planned land and assisted through loans and house construction (Tajudeen 'et al' 2006). Sudan has established the authority for planning and reorganization of squatter areas since early eighties. Its strategy was designated to demolition new developments, translocation of some others, and promotion of the very old ones. The experience was successful in some cases, as the examples of translocation of Ishash Fellatah to the outskirt of Khartoum town, and the promotion of Cartoon Kessala into Hai Baraka in east Nile locality. But such efforts were not always successful, when these squatter developments were associated with political issues of the conflict between north and South Sudan before Nivasha agreement in 2005.

This study objects to judge for improvement or not in environmental health conditions in the squatter area of May and based on that proposed a model for the promotion of environmental health conditions in this squatter area.

Greater Khartoum consists ofthe three towns of Khartoum, Khartoum north and Omdurman (Figure1). Modern Khartoum town started with the Turku-

Egyptian rule in the nineteenth century and in early 20th century the Anglo-Egyptian rule re-established it as the capital of the Sudan (Walsh et al 1994). Similarly, Khartoum north started on the fringe of the right bank of the Blue Nile on a small strip (Gleichen 1905), while Omdurman developed as a narrow strip along the river Nile centered on the Imam Mahadi Tomb (Abu Saliem 1970). Through time the three towns grew rapidly due to urban residential plans, and unofficial land sale by native population (Figure 1).

There are three types of land categorization depicted by figure 1, including occupied residential areas, proposed residential areas, and not specified areas which are miscellaneously used for agricultural, residential and military purposes. Within this urban mass, older squatter areas grew, and furthermore recent growth of squatter settlements has been in areas indicated to ''not specified'' in figure 1The growth of Greater Khartoum's squatter areas was a result of many factors. Land demand for housing increased because of increase of population and migration to Greater Khartoum. Rate of population increase in Greater Khartoum was 4.92 in 1956, and raised to 7.76 in 1973, and to 8.75 in 1983, while reached 13.7 in 1993 (MFEP, Population censuses of Sudan 1956 – 1993). Similarly, number of persons per square kilometer in 1973 was 55.6 persons, 85.5 in 1983 and 169 persons in 1993 (MFEP, Population censuses of Sudan 1956 – 1993). According to population censuses of 1983 and 1993, Khartoum state received 39% and 45% respectively of the internal migration in the country. During the period 1980-1999, Greater Khartoum received between 50-70% of the total displaced population in Sudan in 1990, where they occupied 50 locations in 1991 with a total number of 1,570,000 displaced persons (Banaga 2001). Gradually these concentrations began to be transferred into the old urban mass and old squatter settlements, where their population reached to more than 2,500,000 persons in 2001 (Banaga 2001).

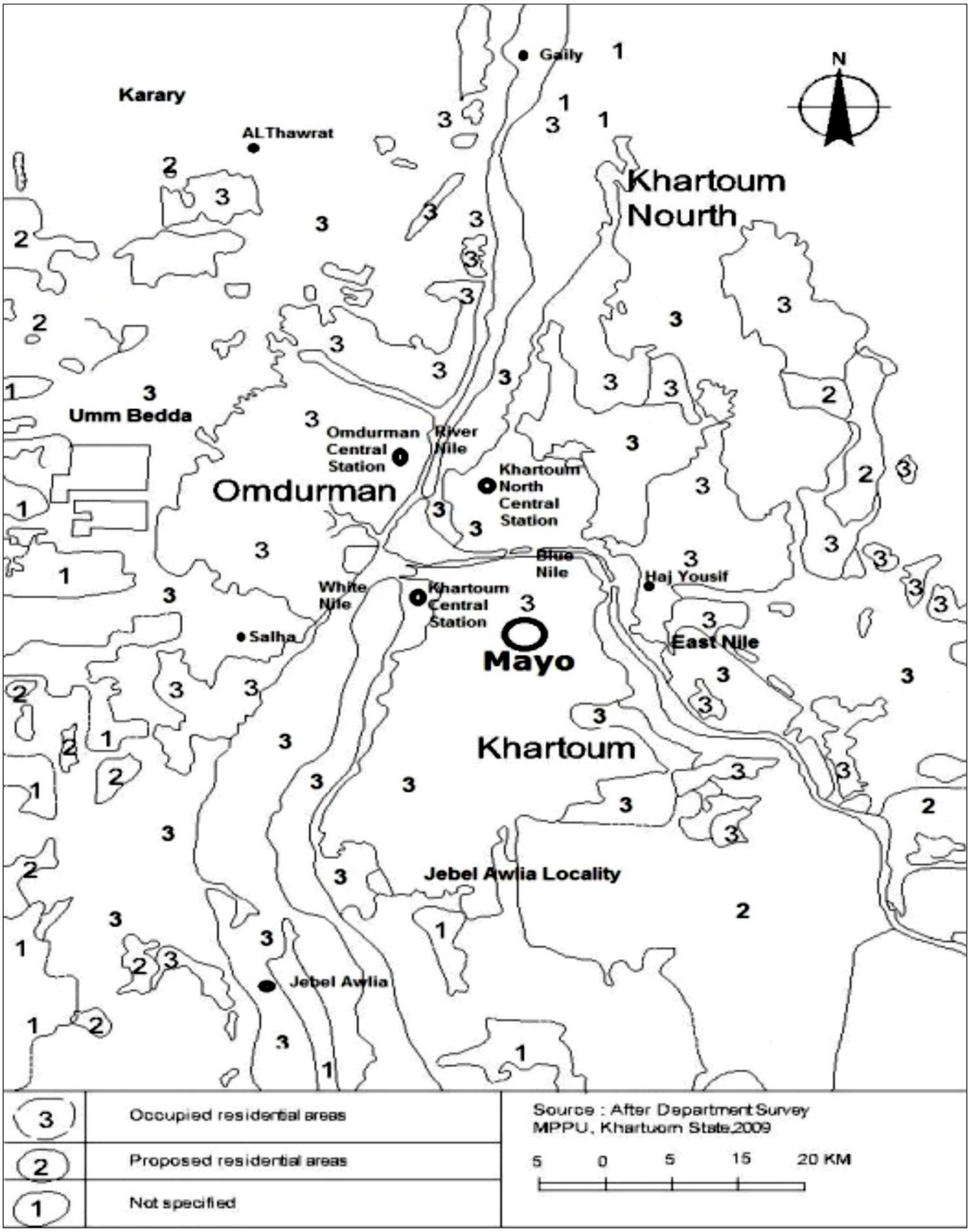

Figure1. Greater Khartoum: location and localities, and location of Mayo area

Mayo area (Figure 1) developed as camp for leprosy patients near Khartoum Industrial area, under the supervision of Ministry of Social Works in 1969. In early 1970s it was transferred to Al-ishash area which was an intra urban squatter settlement. From thereon, Mayo expanded and developed, as it hosted a wide spectrum of western and southern Sudanese tribes, as well as West Africa migrants including Hawsa, Fellata and Quran tribes. Residential demarcation is quite remarkable in Mayo area, where each residential division was mainly occupied by a particular ethnic group or a tribe and named Hai and therefore, there are Fellatah, Quran, Bellalh, Masalit, Fur, Dinka and Nuba residential divisions (Hais). It also became reception area for some urban residents who cannot afford high rent costs or do not own private houses.

Data collection:

The first fieldwork was conducted during March 1987 as Masters Degree research project in Geography submitted to the University of Khartoum by one of the authors. The fieldwork had intended to collect socioeconomic; demographic; nutritional and residential environment data. These included monthly income or households' members, marital status, number of wives, family planning, household educational level, housing conditions including number of rooms, kitchen, bathroom, latrine and its type, size of room, number of windows per room and type of ventilation, and type of water supply). Residential environment data included source of water supply, means of water distribution, cost and pricing, waste disposal system, means of garbage collection, type of food during the day, practicing of breast feeding and its duration, type of food during pregnancy and lactation, type of supplementary food and time of start giving, timing of starting weaning period, type of prohibited food, delivery conditions, practicing of family planning. The fieldwork was supported by three members of Goal Organization medical personnel working in the study area and was headed by one of the authors. The sample size was 880 household representing 10% of the total number of households in the study area according to 1983 population census of the Sudan. Each residential division was allocated by 35 samples. The panel households were chosen according to their accessibility during the fieldwork (non-probability sampling procedure). The names of residential divisions were used for the sample framework where there were 16 residential divisions, including Alwihda; north and south; Fellatah north and south;

Quatati north and south; Bellalah; Dirwa; Wahid wa thalthin; Dink; Quran; Masalit; Tibin; Fur and Alarab. In addition, observation, three water samples were taken from the main borehole; communal water pipe and vendors, and were bacteriological tested for water faecal contaminate

The second fieldwork was conducted in October 2011 by World Vision Organization and was based on focus group discussions. Both primary and secondary data were used in this rapid assessment process. The secondary information such as previous reports, baseline surveys and various inter agency assessments was reviewed. Qualitative data collections tools were employed in order to gather more information on community needs, challenges and proposed area of interventions. Focus group participants identified with purposive sampling in consultations with the community leaders, partners and World Vision Field Staffs Each focus group included 8-15 participants. A complete set of open -ended checklist was applied in the area of 1) food security and natural resources, 2) Water and Sanitation, 3) Health and Nutrition, and 4) Gender and Child Care. The focus group was conducted with four types of groups such as Men, Women, Boys and Girls. The checklists of the focus groups discussions were developed to identify the major findings, Food Security, Health and Nutrition, Water and Sanitation, Gender and Child Care. World Vision staff visited the schools, health clinics and primary resource centers used by the target community in order to assess their physical condition. During the focus group discussion, around 6 basic schools and 2 secondary schools are located nearby or within the communities.

Figure 3. Mayo in 2011
Source: World Vision Northern Sudan, 2012

The used renges model:

The objective of this study, in addition to judge for improvement or not in environmental health conditions I Mayo area, is to propose a model for the promotion of environmental health conditions in this squatter area. The study proposes the "RENGES" (**R**esidential **En**vironment; **G**eography; **E**ducation; **S**ociety) model (see Figure 2).This model considers areas of geographic location, socioeconomic and demographic and nutritional aspects of the society, as well as residential environment characteristics. The RENGES model shows sources of environmental health conditions which are hazardous to the community, including high fertility rates, lack of adequate income, low education and unhygienic standards; inappropriate individual and community health practices; and low nutritional standards. Intervention for the promotion of environmental health conditions, based on environmental health information and geographical information, could be done through education and building capacity of the society. The main objective of the RENGES model is to promote environmental health conditions and reduce environmental health risks Mayo area. The importance of RENGES comes from its simplicity, its potential to deal with the available resources at the grassroots level, and its affordability for use with any squatter area in any geographic setting. RENGES works like an open ecosystem, with inputs, processes, and outputs. The inputs are environmental health standards of adequate water supply, sanitation and health services (residential environment), and geographical information concerns with residential environment as well as environmental health information; and education (educational), and demographic, socioeconomic and nutritional characteristics of the population, (societal), the processes are the impacts of these inputs on environmental health conditions in the study area; and the outputs are the promotion of environmental health conditions and reduction of environmental health risks in Mayo area.

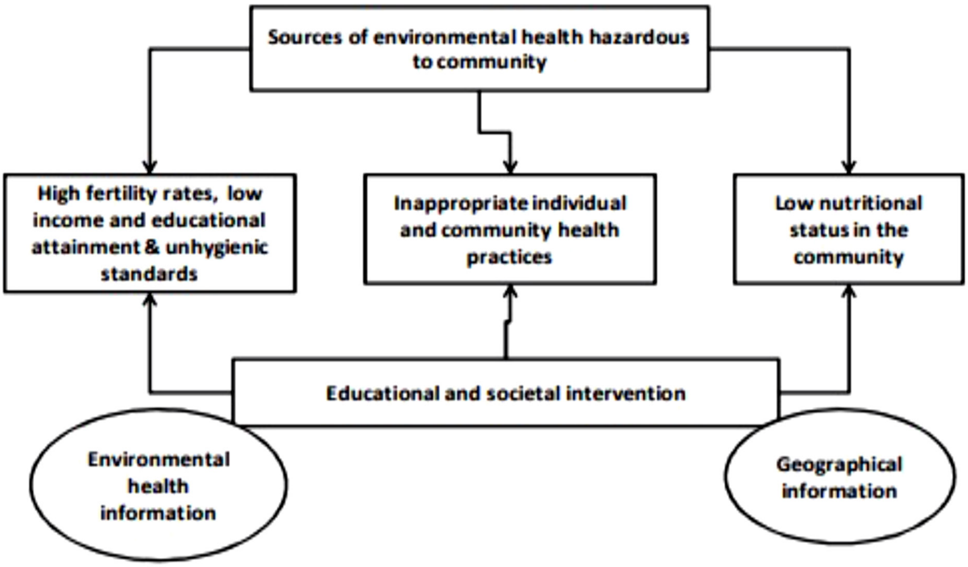

Figure 2. RENGES model for the promotion of environmental health conditions in squatter area of Mayo, southern Khartoum, Sudan

Residential environment data is essential as it provides information on appropriate characteristics of human environment, such as public health and sanitation, water supply and waste disposal systems. Geographical data include information on location, population mobility and density, congestion, and geographic proximity and the role of these factors in increasing/reducing environmental health risks. Environmental health information and geographical information have global, continental, regional, national and local scales. Determination of such geographic scales, particularly the local and national ones, provides a spatial database for dealing with negative impacts of environmental health conditions in squatter areas that will eventually promote its living conditions. Environmental health risks are highly linked with the physical environment—temperature, rainfall, and flooding or aridity which determine their severity and seasonality; the need for such data is substantial for the assessment and prevention of negative impacts of environmental health conditions in such squatter areas. Education is important in the promotion of the general residential environment and reduction of environmental health risks. An educated society will, of course, have knowledge about personal hygiene, environmental sanitation, disease transmission, and infection. Health education will create awareness of the environmental health risks and ways of avoiding their negative impacts. In addition, social capacity building through collective work and civil or voluntary organizations can work to assess and combat/reduce these negative impacts. Society building capacity includes activation of human resources for utmost management of residential environment and promotion ofliving conditions. The application of RENGES model in Mayo area will be further outlined following a review of the results of these two surveys. The major strengths of this model are its simplicity, its potentiality to deal with the current environmental health problems at the grassroots level, and its affordability for use with any environmental health problem in this geographic setting. However, the potential challenges one might expect in trying to implement this model might be migration, due to political instability in Sudan as well as drought, to the study area that will cause overpressure on meager environmental health services and infrastructure. In addition, since there are many gabs and divides that hinder reliable management of environmental health services in the study area, it is expected that this might challenge the application of this model.

The most important of these are gabs in knowledge base and capacity development, absence of comprehensive environmental health policy; lack of coordinated decision making at federal, State, and local levels and gabs between decision makers and target groups. Also, there is a gap between decision makers and stakeholders and bridging this gap is very crucial for success of this model. This purpose could be achieved by encouraging multidisciplinary research that addresses the interests and motivations of decision makers and local society and fulfill the needs of the community.

Demographic and socioeconomic characteristics:

The survey in 2011 gave an average for the household size of 7.5 people per household, which is similar to the results obtained in the survey from 1987, when there was high average parity per household. In 1987, child spacing for an interval of 1 to 1½ years was practiced by 20% of the households surveyed, while 62% of them had a child every 2 years, and 18% for every 2½ years, and 85% of the households did not practice family planning. This is similar to the numbers obtained in the survey made in 2011, when women faced no family planning program and carried too many children. The study area lacks the services provided by the centers of family planning and health education. The population of the study area still has high average parity and does not practice family planning and therefore there was no decline in fertility rate. This high fertility rate proves the total fertility rate in Sudan which was 5.9 births per woman in 1999; and with an annual population growth rate of 2.53 % between 2003 and 2007 and the natural rate of increase of 41.23 per 1 000 in 2006 (Ministry of Health, Sudan. 2008). It also agrees with the slum population growth in Dhaka which has doubled within the last decade reaching 3.4 million in 2005 (CUS et al., 2006). This population increase is reflected in the expansion of the Greater Khartoum through formal urban residence plans and informal squatter areas (El-Bushra, 1995), which agrees with the general world trend of growth in the squatter settlements which constitute 20 to 80% of the urban settlements in developing countries (ECOSOC, 2005), and with the general trend of urbanization in Sudan where the percentage of urban population is projected to be 46.4 in 2025 while, in 1994 it was 24.2 (UN, 1994).

The results of 2011 survey depicted that women are the major income source and contribute to obtain the household daily needs. More than 70 % of them are mainly involved in vending food items for school children and others, in small business, sometimes poultry rearing, and food processing activities. In addition, most of the families depend on daily labor in constructions making bricks and other petty works. 50% of the households spent up to 10% of their income for the education of their children, while 13% spent 10-25%, 17% spent 25-50% and 7% spent above 50%. The survey made -in 1987, indicated that 80% of the households surveyed depended on women as the main source of income. 56% of the total households surveyed had the lowest income of 100-300 SDG (25- 72 USD) per month, while only 10% of the total households had the highest income of 600-800 SDG (150– 225 USD) per month. The population of the study is still urban poor, and females still the main source of the household income. The dominance of the households with a low income in the study area agrees with the figures from the Sub–Saharan Africa where about half the population is living below the poverty line, with both numbers and percentage on the increase (Alredaisy, et al., 2001). Generally, the expansion of towns and cities in Sudan has been accompanied by a growing number of poor and vulnerable urban dwellers (Sara, 2011). Although Sudan is rich in natural and human resources, 77.5% of the households surveyed in north Sudan were on or below the poverty line (MOL and ILO, 1997]. The study made by the United Nations Development Program in 2005 reported that 75% of the north Sudan population was poor and the majority (80%) is concentrating in rural areas where 30% of them suffered from extreme poverty (United Nations Development Program, 2005). The majority of the urban poor people are dependent on marginal livelihood activities from the informal economy, and their access to safe and sustainable livelihoods is extremely unstable (Sara, 2011). However, the factors influencing the income in the study area might include those operating at the national level including the absence of social development and insufficient productive capital investment (UNDP, 1998), ill-conceived development policies and armed conflicts (Zeng, 2003).

The survey in 2011 showed that, pre-schools and primary schools were not sufficient to admit all applicants. The available schools have very limited concerning the sanitary infrastructure and drinking water facilities, where pupils get water from the nearby water points that use donkey carts. The number of students in one class room reached even 130 students. High school fees for students is one of the major reasons for school dropout and a decreased enrollment rate, and children sometimes walk 30-60 minutes to reach the nearest schools. The survey made in 1987 showed that illiterate members of the households represented 33% of the total percentage of educational attainment. Those who completed primary school were only 29%, while those who completed secondary school were only 4%. Educational attainment did not improve between the two surveys, where Illiteracy is still prevalent similar to sub -Saharan Africa, where a large number of children remain out of school and for those who do enroll, less than half complete the primary education (Johnson, 2008), and nearly 78 million of the region's secondary school-aged children were not enrolled in secondary school (UNESCO, 2009).

Water and Sanitation:

In 2011, ½ of the households had access to communal water pumps, and 84% of them are served by vendors. This is similar to the results obtained during the survey made in 1987, where 95% of the households were served by vendors, and only 3% depend on the communal water pumps, while 2% had access to home piped water supply. There was a reduction by 11% of the households served by vendor, which might be attributed to a higher access to communal water pumps in 2011. There was no indication to home piped water service during the survey conducted in 2011, although there was small portion of the population who had access to that type of service in 1987. This is similar to Dhaka, where slum population suffers from acute shortage of potable water (Akbar et al., 2007).

In 2011, there was difficult to have access to water mainly because of high costs. The estimated figures showed that the cost of water could reach up to three times the cost of the piped water in Khartoum City that was 16 Sudanese Guinea (4 USD) per month. A family from Mayo had to pay 48 Sudanese Guinea (12 USD) monthly to purchase water. This equals the water tariff for first class residential areas in Greater Khartoum. This cost, if compared to the one from 1987, when the price of water was fixed by the vendors at a quarter Sudanese Guinea (¼ USD) for a tin of 4 British Gallons (18 litres), that was much less. The calculations made for the cost of water purchased by a household with an average of 6 members, during 1987, gave 1 USD per day or 30 USD per month, which is seven times less the cost in 2011. Most of the households cannot afford that cost and they reduced their consumption or use communal pipes. But this is not always the case, as resulted during the survey made in 2011, when during a normal season a water tank of 216 liters costs 5 Sudanese Guinea (1¼ USD), and during rainy season, the same tank of water costs between 8 (2 USD) to 10 Sudanese Guinea (2½ USD).

Table 1. The presence or absence of faecal contamination in the water from the Mayo area in 1987

Source of sample		MPN. Coli/100 ML	E. Coli type 1 / 100 ML
1-	Borehole	14	Positive
2-	Communal pipe	7	Positive
3-	Vendor	Present	Positive
4-	Borehole	Zero	Zero
5-	Vendor	present	ve

Water provision during the rainy season is more expensive due to poor roads, bad drainage of stagnant water which causes the flooding of the water points and makes them difficult to access. This is similar to the situation in 1987, when stagnant water during the rainy season prevented the provision of drinking water provided by the vendors, as attributed to the same factors in 2011. The high expenditure for water in situations of low income, big households and spreading illiteracy has many consequences. One consequence is that in a household with a low-income a surplus of water is very expensive, representing a substantial proportion of the total income. This has important consequences for the economic appraisal of rural water supply. With regard to affordability, households are unable to pay for water at the current cost. A high proportion of people would be unable to pay the actual costs of water. The revenue that may realistically be expected to be recovered from these households in the future lies somewhere between what they are able to pay and what they are presently willing to pay. Another consequence is the lack of elasticity and the repercussions on expenditure for food, education, health, etc., would imperatively be retarded (Sara, 2011). The high price of water in urban Sudan is probably a major cause of the malnutrition that prevails in the squatter areas (Sandy et al, 1992). The inadequate water supply and high expenditure for water in situations of low income, big households, and spreading of illiteracy have many consequences. One consequence is that inadequate water supply causes water related diseases, for example, access to in-yard water sources improved child health in China; only when mothers were relatively well educated (Mangyo, 2008).

Although one-third of the households had access to clean water in 2011, they spend 40 minutes to travel in order to have access to communal pipes. This time factor was also nominated in 1987. Similarly, both investigations agreed on the time factor, even when the boreholes were the major source of water; there were frequent complaints in relation to shortage of water and long queues to get water, while more than 50% of the existing water sources were not functioning. In 2011, the poor follow up and maintenance of the water sources resulted in poor hygiene conditions and access to water supply. In 2011; only children were reported as the ones primarily responsible for fetching water, while in 1987,both women and children performed that job. The field investigation made in 2011 showed that the water from the donkey carts was often contaminated between the source and the household. In 1987, bacteriological test of water gave the figures shown in table 1. Table 1 shows that, faecal contamination in Mayo exceeds the limit of 10/1000 ML; documented by World Health Organization in 1983, which is unsuitable for human consumption. The boreholes are not the source of water contamination. Vendors are the main source of water faecal contamination. This is because; barrels and vendors are filthy. Moreover, while they were waiting for their turns in a long queue; animal faeces and urine enter the borehole which was improperly protected.

The investigation in 1987 showed that, the expected health effects of contaminated water on the population are related to water – borne diseases such as diarrhea and typhoid which are responsible for 52.7% of the overall specific causes of death among children with ages between 1 – 5 years as well as malaria which accounted for 52.25% among other infections. This is similar to the results obtained in 2011, where clinical records showed that most diseases are related to the lack of washing facilities, where the diarrheas, eye infections and malaria, are the major and the most common diseases among children. The causes for these infectious diseases were due to the lack of a clean and hygienic environment. The comparison between the results obtained during the two investigations showed no improvement in water accessibility and affordability among the population living in the Mayo area.

In 2011, more than 60% of the Mayo population had no access to household latrines. People either defecated in open areas, in neighbors' latrines, or in public latrines. 35% households did not have separate latrine for defecation. 81% of the people with no latrine reported to use the neighbor's latrine and 19% reported to use either bushes or open places or a public latrine or pits. 88% of those who owned a separate latrine had a traditional one. For those who had a separate latrine, feces could be visible during the visit in the household over the slab or on the pan inside the latrine infrastructure. In 1987, 51.7% of the households owned private latrines, 31.39% shared common latrines, while 16.68% did not have latrines. Pit latrines or borehole latrines are the dominant types among those who had latrines. Nearly 50% of thepopulation were using common latrines or excreted in the open spaces. The places of defecation for those who did not own latrines included the settlement in the neighborhood (52%), buckets (5%) or neighbors' latrines (43%). The bucket is used for defecation and when filled up, it will be disposed in the immediate vicinity of the area. Private latrines do not meet the sanitary requirements and the roofs, doors and windows do respect the health regulations. They had no cover which made them accessible to flies and they were dug down up to 3 meters depth due to the geology of the area. In 2011, the traditional latrine was a type of pit latrine from where flies could easily come and fly to other category of latrine, which were more unhygienic than the traditional latrines. More than 55% of the population had no access to sanitary facilities and therefore they practiced open defecation. Open defecation is the general norm in the area. A special ''defecation area'' has been allocated. This situation might be similar to that in Dhaka, when in 1999, less than 25% of the people were served by sewage treatment facilities (Kamal et al., 1999), and therefore open latrines are also a source of surface and groundwater contamination (UNDP, 1987). Even today slum people usually build open-latrines on the roadside or near the water bodies thus, severe water pollution occurs when natural runoff drains and transports human wastes to the surrounding water bodies.

This unhygienic home environment was aggravated even more in 2011, when animals and people lived in the same space, therefore creating health problem. This situation is similar to the one in 1987, where 40% of the population used to keep goats (17%); sheep (3%); pigeons (8%); and chickens (12%), and there was no proper place to keep animals separately.

Deaths of infants and young children between 1-5 years old, as a percentage of all deaths, were calculated at 62% in the households who used to have no special fence to keep animals compared to 38% of deaths recorded in households that have special places to keep animals.

In 1987, 46% of the households surveyed indicated that they dispose wastes in the immediate vicinity of the area, while 32% disposed them in the street just in front of their houses, and only 21% used to burn these wastes. There was a complete absence of waste disposal system and therefore, the waste accumulated into huge piles in the streets. There were certain organic residues of distillation of traditional alcohol of liquors and beer. The odor was very strong and annoying. These wastes mixed with the rain during the rainy season and made a suitable niche for breeding of flies and mosquitoes. In 2011, there was a lack of garbage containers and when the garbage was collected there were no vehicles to take it away for disposal. The management of solid waste is a huge challenge where piles of solid wastes are dumped at an empty and open space close to dwellings. The stagnant water harbored mosquitoes and other insects and ultimately aggravated the spread of malaria and otherdiseases. In 1987, during the rainy season, the severity of diseases was highly correlated with the nature of development of this area which lacked proper streets, drainage system for storm water, very narrow streets that impeded the water from the rain to drain and the stagnant rain water was a suitable habitat for mosquitoes breeding and the spread of malaria. 70% of the households surveyed indicated that rainy season was the peak for the spread of infectious diseases, in opposition to the winter season (3%) and autumn (7%). The general result of the two surveys agrees on no improvement in the residential environment. This situation might be similar to that in Dhaka where the waste disposal method practiced was open dumping on plain ground or at the outskirts of the city (UNEP, 2006), while large portion of domestic wastes remained uncollected, and over 70% of slum dwellers do not have access to safe sanitation (CUS et al., 2006). There was also noted an increase of the solid waste discharged from 1040 tons/day in 1985 to 3200 tons/day in 2004 (JICA, 2005).

Health and nutrition:

In 2011, 52.5% of the women surveyed consulted traditional healers, similar to 1987 when traditional healers were consulted during pregnancy, lactation period by 73.9% of the women surveyed. Mothers consulted traditional healers to cure their ill children as they believed in folk medicine and lacked the money to cover the medical expenses. Many types of herbs were given to treat various diseases. Also, in 2011, most of the women deliver in the house with the assistance of the Traditional Birth Attendants, and in 1987, 86.38% of women interviewed stated that they delivered their children at home with the assistance of traditional midwives. In 2011, Post anti natal reproductive health care practices for women was limited; they did not go for ante-natal check-up unless there was something serious to consult the health professionals. In 1987, there was no close maternity hospital, and pre-natal care was provided by Goal Organization since 1986

In 2011, pregnant women were suffering from the lack of a balanced diet, which is similar to situation in 1987. The food consumed by pregnant women during their pregnancy period consisted of 37.36% carbohydrates; 4.42% animal protein, and 12.5% vitamins. In 2011, pregnant women did not eat eggs as it was believed to cause sexual exposure of the baby and to cause excessive pain during the delivery of the baby, while honey may cause abortion to a pregnant In 1987, food taboos among pregnant women included the belief for 10.22% of the women that eating camel meat during pregnancy prolongs the gestational period up to 12 months, and 10.45% believe that eating eggs may cause delay of child growth, while 2% believed that some types of fish lead to child physical malformations. In addition, 40.45% of the households investigated stated that all family members eat together, while 60% said that men eat first, then the children and very few said that the children ate first.

During the investigation in 2011, infants were breast fed as initial food immediately after delivery. But due to lack of proper food and the lack of a balanced diet, the mothers had no sufficient milk to beast feed the babies. In 1987, women used to breast feed their children, but the durations of breast feeding were less than one year as stated by 13.33% of the households surveyed; one year (11.11% of the households); and one year and a half (75.55% of the households). Mothers were breast feeding their children for a long period of time as it might be culturally and nutritionally valued. Carbohydrates including local bread and rice constituted 41.38% of each food type during lactation, while animal protein and vitamins constituted 12.22% of the total food nutrients consumed by a household.

The moment when supplementary food was given to children started at the age of 7 months as indicated by 29% of the women surveyed, which was mostly of carbohydrates origin, similar to weaning food which abounded of carbohydrates and lacked proteins and vitamins. Also, the results obtained in 2011 showed that 90% of the people of living in the area suffered a lot from the lack of food and that the food quality was very poor and not diversified. In most households it was unthinkable to get vegetables and milk products as part of their meal. 56% households ate cereal food at least once a day; 52% households ate meat daily; 47% household ate vegetables at least once a day and 3% households never ate cereals during last seven days.

The general findings of this study showed that less animal proteins, vitamins, minerals and abundant cereals are consumed. In the study area, fat and carbohydrates consumed, were lower than 2041.7 calories which was recommended for population in Africa (Latham, 1979). The comparison made between the consumption of calories from the study area and the results obtained pursuant the study made by the Ministry of Agriculture and Forestry of Sudan (FSU, 2005) show that the people in the study area have a low consume of carbohydrates and lower energy intake (430.1 kcal vs. 1962 kcal In African diets, fats usually provide fewer calories than carbohydrates, perhaps only 8 or 10% of the total calories consumed (Latham 1979:50). The term fat includes all fats and oils that are edible and occur in human diets. The high contribution of cereals to energy and protein intake, in the study area, is similar to the area of rural Philippines where 361g/person/day are consumed (Florentino, 1996). Animal protein sources such as meat and milk are less (8.14 g) than the recommended value of 55.3 g (FSU, 2005). One of the main reasons for a generally declining trend in food consumption in the study area is high living costs in Sudan and big households and spreading illiteracy A great number of people are unable to pay the actual costs of food. The revenue that may realistically be expected to be recovered from these households in the future lies somewhere between what they are able to pay and what they are presently willing to pay. Another consequence is the lack of elasticity and repercussions on expenditure for food would imperatively be retarded. The high price of food in urban Sudan is probably a major cause of the malnutrition prevalent in the squatter areas (Sandy et al, 1992). Decreasing income led to marginal or sub-optimal intakes of energy and protein resulting in more prevalence of under-nutrition in rural western

Kordofan of Sudan (Alredaisy and Suleiman, 2010). Many studies in Sudan showed cases of low weight, stunting and wasting among young children because of unequal income distribution, vertically between incomes and horizontally between rural and urban areas (UNDP, 2006).

Food shortage occurs mostly during the rainy season and at the end of every month when most households experience food shortage, because most of the salaried people do not have money. And most of the households cope the food shortage season with the reduction of the number of meals per day, reducing the size of the meal. Also, people use to take food on credit and borrow food. In 1987, 60% of the households surveyed have one meal per day and those who have two meals were around 40%. Survival strategies followed by the population living in the study area are the real reflection of a low income and poverty. This could make one to include the population from the study area within food insecure groups from Sudan. These groups include those people whose food intake provides a less quantity than that recommended for refugees and internally displaced groups (IOM, 1995). In addition, they include rural areas of low crop and animal production; areas of low purchasing power and education and knowledge; areas of low access to health facilities and vulnerable residents who were indirectly affected by the influx of internally displaced population in their communities.

The proposed RENGES model for the promotion of environmental health conditions in Mayo squatter area:

The results of the two surveys depicted low standards in socioeconomic and nutritional characteristics, lack of basic infrastructure or healthy residential environment, which is dramatically influencing environmental health conditions in Mayo area. These results judge for no improvement in the environmental health conditions in Mayo area (see Figure 3). Based on these findings this study could build a very strong case for prioritizing improved infrastructure in addition to educating people for the promotion of environmental health conditions in Mayo squatter area by incorporating the RENGES model(Figure 2).

Promotion of residential environment requires relevant data on the general layout of the area, in relation to topographic and climatic characteristics, housing characteristics, as well as timing of the rainy season to facilitate appropriate planning for control of the expected health hazards. There are gaps in the environmental health conditions in the study area that could be bridged by appropriate intervention. This appropriate intervention could build a case for prioritizing improved infrastructure depending on residential environment information and geographical information (see Figure 2). Residential environment information could be obtained from local administrations and field surveys executed by local government, NGOs or researchers. Geographical information should relate to population growth, increase, mobility, migration, density, and concentration in order to detect hazardous areas. Access to a map showing residential expansion and population movement within various squatter areas, and third-class residential area of Greater Khartoum, can help to forecast future trends of population-movement and their consequences on public health in such squatter areas. Geographical and residential environmental information for the RENGES model can also benefit from the available infectious and nutritional diseases data, which have grown worldwide with efforts to improve disease surveillance and the initiation of population-based disease incidence studies, in addition to advances in the understanding of the age distribution of such diseases , allowing for measurement of incidence rates among narrow age cohorts to be more accurately extrapolated to the general population. It is generally assumed that there is a need to educate people about adequate and basics of environmental health. In reality, however, people are probably very much aware of the health risks related to inadequate environmental health but, because of poor water and sanitary infrastructure and because of perhaps population density, it is very difficult to prevent the expected negative impacts. People in squatter area of Mayo can be educated about residential environment sanitation and symptoms, treatment of various diseases related to inadequate environmental health as well as prevention through school subjects such as geography and biology and also through mosques, churches, adult education, media education, mobile cinema, and distance education. In Khartoum state there is a local broadcasting and television station, many universities, and distance-education centers. All these facilities can be used to educate people about adequate residential environment sanitation and the diseases related to inadequate environmental health. Educational technologies which encompass electronic-based delivery methods and innovations in instructional design such as adult education, problem-based learning, and competency-based training can help to innovate information on residential environment sanitation, community health and insanitary related diseases. Distance learning which includes synchronous methods that link learners who are separated by geographic distance and allow for simultaneous interaction and asynchronous methods can allow for interaction at different times. In addition, health education about personal hygiene, especially regarding hand washing after toilet use and before food preparation; use of safe drinking water; excluding disease carriers from food handling; and antibiotic treatment, family planning, is essential for the promotion of the community of such squatter area. Strategies for administration of vaccines for preventing childhood diseases should be deployed on a wide scale in RENGES model, bearing in mind that vaccines can control these diseases only to a limited extent and that the eradication of a carrier state can be difficult.

The responsible bodies for the implementation of the model might Peoples' committees; Ministry of human resource development; Ministry of Justice; and Ministry of Information. Realizing this proposed model depends on collective work by these bodies. The duties of People's Committees should focus on transferring information to local communities on innovative directions for environmental health conditions such as rational use of water and the impacts of misuse as well as health hazards related to water, through youth clubs, and religious men and women in those communities. Ministry of Human Resource Development should train local people on how to rationally manage their residential areas through community education for sustainable development (ESD). Methodology for implementing ESD should firstly, target stakeholders who could be middle leaders, including executive committee of local non-governmental organization, local public committee and official officers and teachers. Awareness creation is a step towards drawing attention and building capacities of the stakeholders to deal with the challenges of environmental health problems. Through increased knowledge and awareness, the community can be motivated to take better care of their environmental health. School teachers should be trained on environmental health education, particularly in primary schools. Introduction of education for sustainable development (ESD) into schools' curricula, students' activities, mass media and youth clubs will inform the community on rational deal with their residential environment. Society capacity building and awareness in Mayo area can be enhanced through religious and cultural norms encouraging personal hygiene and neighborhood sanitation where God's rewards are endless, conscious use of herbal medicine, and the help of traditional healers and curers capable of transmitting correct information on risks to diseases related to inadequate environmental health to indigenous people. Youth clubs and school vacations can be opportunities for volunteer work in society capacity building through campaigns. Charitable donations can be used to provide sanitary materials for poor people and for public bathrooms; posters and other materials to raise awareness about public gathering places; and funding for local people's committees, administrative localities, and youth clubs to work for environmental sanitation in their neighborhoods, including monitoring suspected insect breeding locations, for example.

The Ministry of Justice could protect any environmental health policy through legislations and management and could also execute penalties on misuse of residential environment or on corruption in the environmental health sector. But this cannot be accomplished without the role of Ministry of Information. The motivation of the community to maintain and protect their residential environment is of critical importance through TV, Radio, and Newspapers which can transfer knowledge about adequate environmental health conditions. In addition, coordination between governmental bodies responsible for environmental health provision and management with reference to local community is essential. Participatory approach, through Peoples' Committees is important in the assessment and reduction of risks to inadequate environmental health conditions. A participating community will, of course, have knowledge about environmental health value, and rights for oneself and others, as well as the impacts of environmental health degradation on residential environment. In addition, social capacity building through participatory work and civil or voluntary organizations can work to assess and alleviate environmental health problems through innovative directions, such as waste disposal collection, nutrition awareness among households and water utilization in the study area.

The model can be implemented through two phases. In the first phase, it is necessary to provide careful assessment of the area's environmental health conditions; and local environmental legislations. The second phase includes coordination system of environmental health management; and participatory approach to its management between governmental bodies responsible for environmental health provision and management with reference to local community. A participating community will, of course, have knowledge about environmental health value, its conservation, and its rights for oneself and others, as well as the impacts of environmental degradation on water sources.

This model can be used carefully to overcome the existing environmental health conditions in the study area through adopting the proposed to phases and by considering the gabs and divides that might hinder its reliable management that have been already outlined in section 1-3. The application of the RENGES model in Mayo area can work to promote environmental health conditions in order to decide on appropriate methods through activation of the inputs, processes, and outputs outlined by this model, with the ultimate result of promoting environmental health

in squatter areas in urban Sudan. However, this proposed model to be more practical and effective should put consideration to challenges to implementation, gap in knowledge/work to be done/data to improve and evolve the model and Implications of future events on the model (e.g. population increase and high demand for housing).

Conclusions:

1. A sustainable integrated model to promote the environmental health conditions is need for the urban squatter areas given the current and projected housing stress.
2. Environmental health conditions including social, economic, nutritional and residential environment characteristics have been assessed and a model proposed.
3. The model is awesome because it considers the geography and the environmental health conditions as well as the community at the grass root level.
4. As the model is implemented and continues to evolve the results will be shared with academic community
5. There is hope provided there is wise urban management in Sudan.

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