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RESEARCH ARTICLE

APPLICATION OF REMOTE SENSING AND GEOGRAPHICAL POSITIONING SYSTEM TO SPATIAL DISTRIBUTION OF GLOSSINA FUSCIPES FUSCIPES (DIPTERA: GLOSSINIDAE) IN KAJO-KEJI COUNTY SOUTH SUDAN.

[*]Yatta S. Lukaw[1], David O. Evuk [2], Mubarak M. Abdelrahman[3], Yassir O. Mohammed[4], Erneo B. Ochi[5], Intisar E. Elraya[3] and Yousif R. Sulieman[6].

1. University of Juba, College of Natural Resources and Environmental Studies, Department of Basic Sciences.
2. University of Juba, College of Natural Resources and Environmental Studies, Department of Geology and Mining, P.O. Box 82 Juba South Sudan.
3. Tropical Medicine Research Institute, P.O. Box 1304, Khartoum, Sudan.
4. Veterinary Research Institute, P.O. Box 8067, Khartoum, Sudan.
5. University of Juba, College of Natural Resources and Environmental Studies, Department of Animal Production, P.O. Box 82 Juba South Sudan
6. University of Bahri, College of Natural Resources and Environmental Studies, Department of Animal Production, P.O. Box 1660 Khartoum North, Sudan.

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Corresponding Author

Yatta S. Lukaw.

Abstract

Tsetse flies are the sole biological vectors of Human African Trypanosomiasis (HAT) in sub-Saharan Africa. *Glossina fuscipes fuscipes* act as tsetse vectors of HAT in Kajo-keji County (KKC) South Sudan. Studies on the spatial distribution of tsetse flies are imperative for the control of trypanosomiasis in the endemic foci. A 2-year- study was carried out to spot spatial distribution of *G.f. fuscipes* in four Payams of KKC. 56 unbaited biconical traps were deployed in various ecosystems assumed to habituate tsetse fliesand coordinates of the sites where traps were deployed were recordedusing Global Positioning System (GPS). Remote Sensing (RS) and Geographical Information System (GIS) were applied and map was generated. This map revealed spatial distribution of *G.f.fuscipes* in eight streams of four Payams, KKC as a function of apparent density of flies/trap/day and infection rates (IR%) of *Trypanosoma brucei gambiense* in *G.f.fuscipes*. Both RS and GIS are useful tools that could be incorporated into decision-making process to prioritize target areas for vector control strategy. Further study on relevant technology is needed in Western and Eastern Equatoria States State South Sudan.

Introduction:-

Tsetse flies are important veterinary and medical biological vectors of a haemoprotozoan parasite of Genus Trypanosoma, the cause of Human African Trypanosomiasis (HAT) or sleeping sickness in humans and Nagana in Cattle (Ciosi et al., 2014*). Glossina f. fuscipes* is one of the seven species and subspecies of tsetse flies infesting both humans and animals in South Sudan (Snow, 1983). Moreover, evidence has shown that *G. f. fuscipes* is the main vector of T.brucei gambiense in Central Equatoria State (CES) (Mohammed et al., 2010; Lukaw et al. , 2014) .

Disease surveillance and monitoring are major components of vector and disease control. But this may require frequent human facility at the sampling sites. Apart from the financial costs, inaccessibility to some of the areas due to a pervasive insecurity, such problems could be resolved by the integration of both remote sensing (RS) and geographic information systems (GIS) in vector dynamics and disease epidemiology(Oladejo and Ajibola,2014).RS and GIS areused to identify and map the potential habitats of parasites and disease vectors; predict alterations in vector and parasite populations, monitoring quantitative and qualitative alterations in the respective habitats; and plan control programmes, with maps indicating areas of greater and lesser risk of the disease (Hugh-Jones, 1989).

Moreover, the satellite surveillance can be used for monitoring of several environmental variables such as temperature, precipitation, humidity, wind speed and direction that influences the activity of pathogens, vectors and their interactions with human and animal hosts (Singh et al., 2015).

Mapping and modeling methods used to study the spatial distribution and spread of vector-borne and directly transmitted infectious diseases are becoming increasingly widespread and sophisticated as the field of spatial epidemiology grows (Linrad and Tatem, 2012).

No updates on spatial distribution of tsetse flies are made in South Sudan. Most of the studies describing distribution of tsetse flies were dated back to 5 decades ago. This study aims at mapping the spatial distribution of *G. f. fuscipes* in eight streams of four Payams in KKC using RS and GIS technologies. Such study could providebaseline data on tsetse flies and trypanosomiasis (T&T) for developing control strategy by the key stakeholders in South Sudan.

Materials and Methods:-

Study Area:-

KKC is located in CES at the extreme southern end of South Sudan between lat. 3.67203- 4.13238 N and long 31.1004 -31.8172 E (Map 1) covering an area of 113,000 $Km^{2.}$. KKC is a tropical rainforest zone with moderate soil fertility. The annual rainfall ranges between 1200-2000 mm for about 8 months from March to October. The mean maxima temperatures range between 30-32^{o}C in dry season. The mean minima range between 19-27^{o}C in rainy season. Relative humidity usually stands at 55 %.

Remote Sensing (RS) and Geographical Information System (GIS) Data Acquisition:-

A large-scale analog drainage map from the Survey of South Sudan (1:50,000) was scanned and georeferenced to serve as a basis for digitizing hydrology and Payams of KKC into a GIS geodatabase. A 185 x 185 km Landsat 7 ETM^{+} imagery (Bands 1, 2, 3, 4, 5, and 7) of path/row 172/57, centered on CES and dated January 2011and December 2012, was acquired Global Land Cover Facility site. The resolutions of these data are 30 x 30 m. Control points (prominent land features) were located using a hand-held Garmini 62 - GPS, and used to rectify the ETM data to subpixel precision. ERDAS IMAGINE image processing software was used for processing of the satellite data (Figure 1).

The GIS layers created for the 8 streams were digitized and the generated data models were used to create maps (Figures 1 and 3). The schemes in the data model included: names of the sampled streams, sampling sites, targeted Payams of KKC, G.f.fuscipes, the flies apparent density/trap/day and IR%. Landsat 7 ETM^{+} imageries scene of path/row 172/57 for the different seasons were downloaded from the Global Land Cover Facility. The imageries were rectified using ground control points collected by the GPS. Layer stacking for bands 1, 2, 3, 4, 5 and 7 was performed on the imageries using Erdas Imagine software for the different seasons. True color band combination 321 was performed for the images then pan-sharpened with panchromatic band 8 using Erdas imagine 2011 software to produce 15m resolution imageries. A geodatabase containing satellite imageries and other map layers was created using ArcGIS 10.1 for the study area.

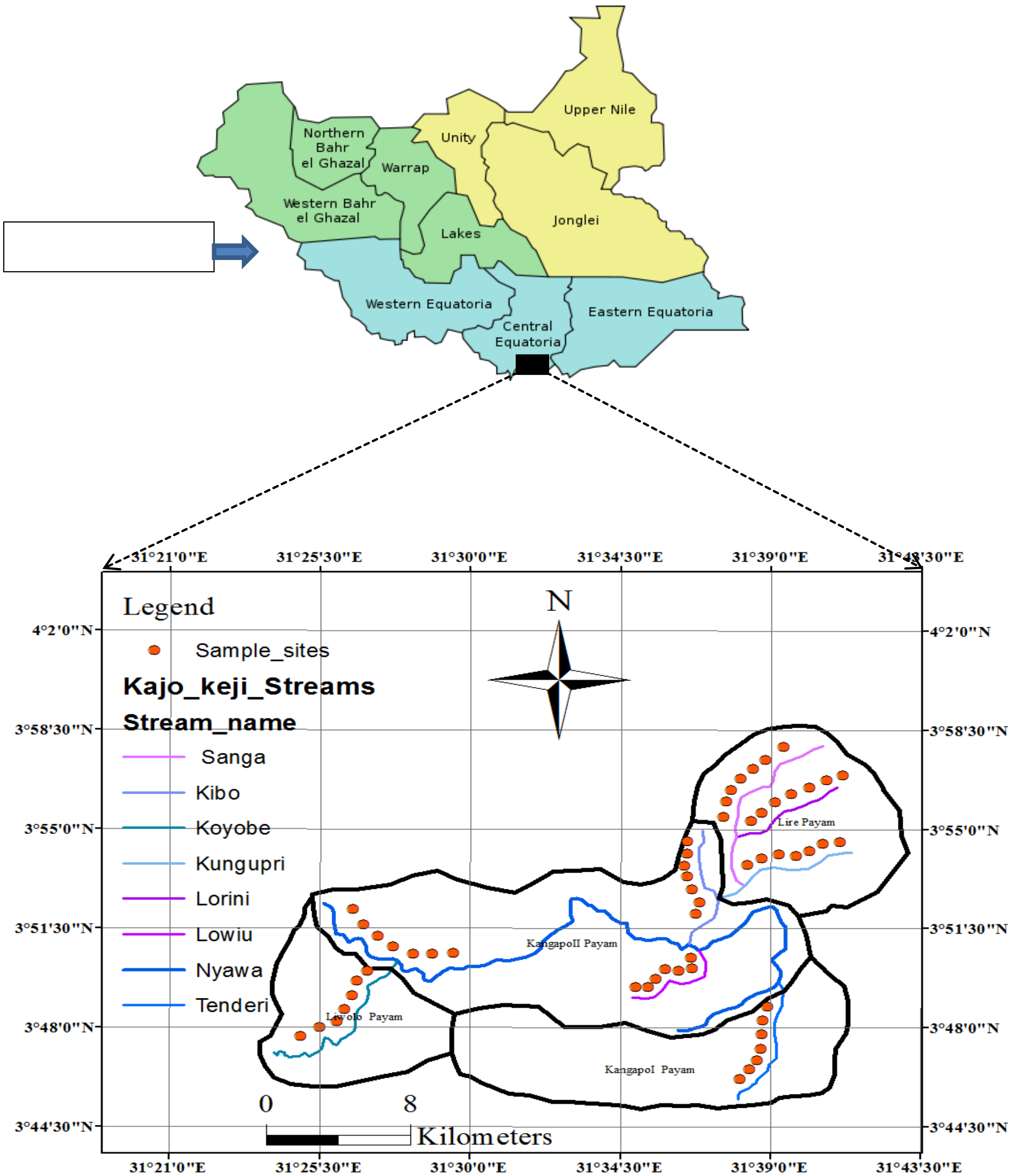

Figure 1:- Map of Study area showing sampling sites.

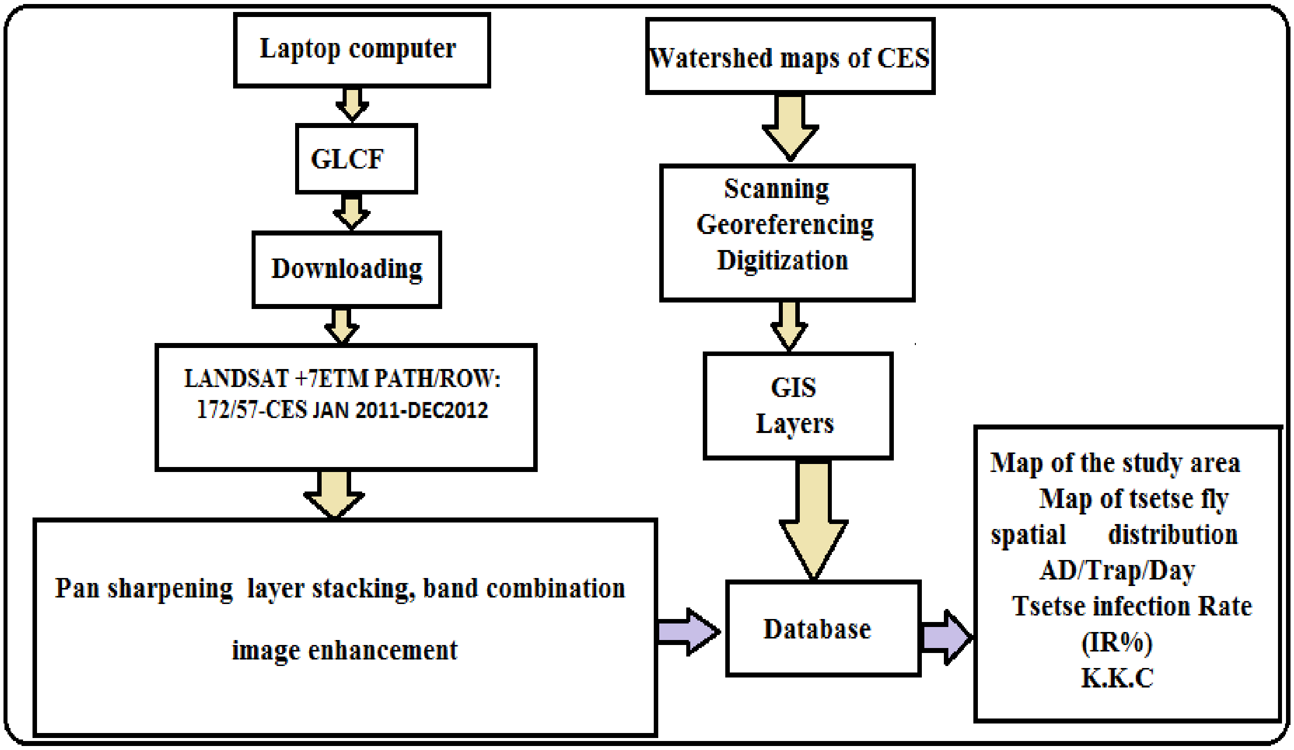

Figure 2:- Spatial data acquisition processes.

Results:-

The distribution map of G.f. fuscipes shows the fly ADT/day and IR% in the eight streams in the study area. The map also indicates that G. f. fuscipes is the only tsetse species widely distributed during the study period. G.f.fuscipes ADT/day was in the orders of ($0 \leq AD \leq 5$) in Tenderi stream of Kangapo I Payam, Kibo stream of Kangapo II Payam, Lowiu stream of Liwolo Payam, Lorini , Sanga and Kuguprical streams of Lire Payam (Map 1). The ADT of G.f. fuscipes was in the range ($5 \leq AD \leq 10$) in Nyawa stream located in Kangapo II Payam and this ranged was classified as low AD (Map 1). However, it was in the range ($10 \leq AD \leq 20$) flies/trap/day in Koyobe stream of Liwolo Payam and thus regarded as high AD (Map 1). Low infection rate ($0\% \leq IR \leq 7\%$) was recorded in Lowiu stream of Liwolo Payam, Sanga, Lorini and Kunguprical streams of Lire Payam and in Tenderi stream of Kangapo I Payam (Map 1). However, a high infection rate ($8 \leq IR \leq 20\%$) was recorded in Kibo, Lowiu and Nyawa streams of Kangapo II Payam and in Koyobe stream of Liwolo Payam (Fig. 3).The distribution of HAT agent(T. b. gambiense), the cause of West African Trypanosomosis followed closely the distribution of its vector (Glossina f.fuscipes) a riverine species of the palpalis group incriminated for HAT in South Sudan(Map 3).

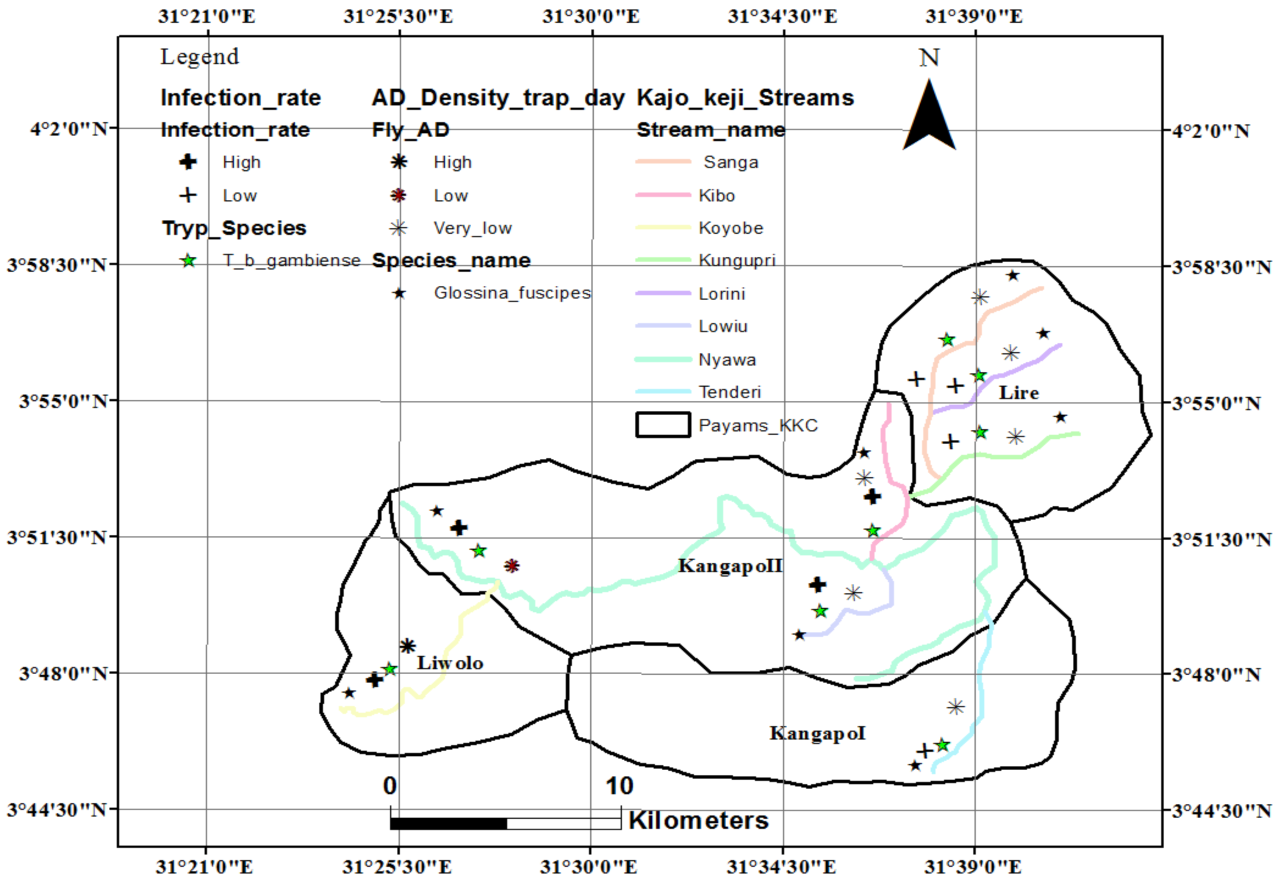

Figure 3:- Spatial Distribution of Trypanosoma brucei gambiense relative to occurrence of Glossina fuscipes fuscipes in streams of Kajo-keji County, South Sudan

Discussions:-

RS and GIS proved to be reliable tools in T&T distribution. Evidence has shown that several studies explore remotely sensed environmental factors that may be associated with T&T distribution(Rogers and Randolph,1991; Kitron et al.,1996; Robinson et al.,1997). Such techniques have played significant roles in increasing our capacity to observe environment (De la Rocque et al.,2004).Mapping the distribution and abundance of tsetse flies assists in predicting trypanosomiasis distributions and developing rational strategies for disease and vector control (Albert et al., 2015).

The use of GIS software now makes it cheaper and easier to produce maps which can serve as useful tools for policy discussion, and allow for analysis of factors that would influence the disease patterns (Thumbi et al., 2010).

It appears that molecular studies coupled with geo-referenced information of vector, host and relevant environmental parameters, combined in a GIS could be robust in providing information on the pattern and the trend of the distribution of both the vectors and parasites. This study showed that the existence of a large fly catches in Nyawa and Koyobe streams, KKC could confirm the fly high apparent densities (Map3). This might be due to dense vegetation of tall shaded trees and thicket forests which provide breeding sites and for tsetse and vertebrate hosts. Consequently, such environmental parameters have created suitable conditions for the survival of flies (Bouyer et al., 2005 ; Okoh et al., 2011).

It has been therefore demonstrated in the tsetse distribution map (Fly AD and infection rate) that distribution of HAT is associated with the presence or absence of the infected flies. This has become possible to map using the RS and GIS that are able to predict the presence or absence of tsetse species with accuracies (Hay et al.,1997). RS data can be used to indicate the presence or absence of vectors of diseases and their parasitic hosts (De la Rocque et al., 2004).The approach developed in this study has proved to be capable of producing valuable information on the geographical distribution of all tsetse species of major medical and veterinary importance (Cecchi et al., 2015).

Conclusion:-

Methodology to assemble spatial databases on the occurrence, apparent density and infection rate of Glossina species were developed in KKC, South Sudan. This would help generate a comprehensive map for the spatial and temporal distribution of Glossina species of South Sudan. Mapping of all tsetse species of medical and veterinary importance is imperative for providing vital information for control strategy. Further studies are needed to apply relevant technology for mapping T&T in other HAT endemic foci of Western and Eastern Equatoria States, South Sudan.

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