International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-6, August 2013

GIS Integrated Epidemiological Indices for Risk Area Identification towards Malaria Control Measures

Abdul Qayum, Andrew Michael Lynn, Rakesh Arya, Sanjay K Jaiswal

Abstract:*The exponential increase in the mosquito born diseases has been found in the recent past. It is primarily because of the development of drug resistance of malarial parasites. It has various other reasons including indiscriminate use of pesticides, excessive deforestation and demographic shifts which are responsible for this enhanced rate of spreading of this epidemic.*

The current paper demonstrates a case study and an example of application of GIS integrated epidemiological indices for risk area identification. The main aim of the work is to identify the risk areas priority in the selected region of Eastern Uttar Pradesh (UP), India especially for Gorakhpur, Kushinagar & Maharajganj district region and to assimilate the results obtained from both GIS based and epidemiology. Computerised spatial database and GIS mapping software provides powerful tool for management and analysis of malaria control program. It proves to be a breakthrough towards various control measures. Using ArcGIS; maps were produced and assimilated to malarial hotspots. Further, various epidemiological indices like ABER, API, SPR, SFR were studied to understand malaria epidemicity of eastern UP and aimed to look for any possible bridge between these epidemiological indices.

Key Words: API, ABER, Epidemic, Epidemiology, GIS, Malaria, Mapping, PHC, WHO.

I. INTRODUCTION

Malaria is a protozoal disease caused by infection with parasites of genus Plasmodium and transmitted to man by certain species of infected female Anopheles mosquito[8]. Malaria affects mainly poor, underserved and marginalized populations in remote rural areas which are characterized by inadequate control measures and limited access to health care. In India about 27% population lives in malaria high transmission (>1 case/1000 population) areas and about 58%in low transmission (0-1 case/1000 population) areas. About 92% malaria cases and 97% of deaths due to malaria is reported from North-eastern states ,Chhattisgarh, Jharkhand, Madhya Pradesh, Orrissa, Andhra Pradesh, Maharashtra, Gujraat, Rajasthan, West Bengal and Karnataka[7].

Manuscript published on 30 August 2013.
***** Correspondence Author (s)
Abdul Qayum, Center for Biology & Bioinformatics, School of Computaional & Integrative Scienes, JNU New Delhi India.
Andrew M Lynn (Associate Professor), Center for Biology & Bioinformatics, School of Computational & Integrative Sciences, JNU New Delhi India.
Rakesh Arya, Center for the Study Regional Development, JNU New Delhi India.
Dr. Sanjay K Jaiswal, 3Medical Officer, CHC Seovarhi Kushinagar UP, India.

Malaria is endemic in more than 100 countries and around 40 % of world population is at Malaria risk [7]. Malaria is a major public health problem in India and it has more than 1.5 million people infected with Malaria (Malaria Situation in India). It is local disease but has to be focussed in well planned manner. There has been found an exponential increase in the mosquito born diseases in recent past. It is primarily because of the development of drug resistance of malarial parasites along with several other factors. In the *tarai* region of Eastern Uttar Pradesh the spreading of vector borne diseases becomes uncontrolled especially during rainy seasons.

GIS could be a fantastic tool for disease management as it has inherent ability to manage spatial, non-spatial and temporal data [9]. GIS comprises set of strategies and tools capable of integrating, storing, editing, analyzing and displaying geographically referenced information from various sources [1].

For epidemiological indices; API based malaria maps of India and Uttar Pradesh is taken from National Vector Borne Disease Control Programme Official Website for its microscopic study up to the level of Primary Health Centres (PHCs) & Community Health Centres (CHCs) for the study area. GIS mapping is done at PHC/CHC level of the entire target area. The work mono-fragmented to obtain annual variation of ABER, API & SPR for Gorakhpur district and seasonal variation of Malaria infected people has been generated for Kushinagar & Maharajganj District for the most recent time period up to July-2013.

II. FACTORS BEHIND MALARIA ENDEMICITY:

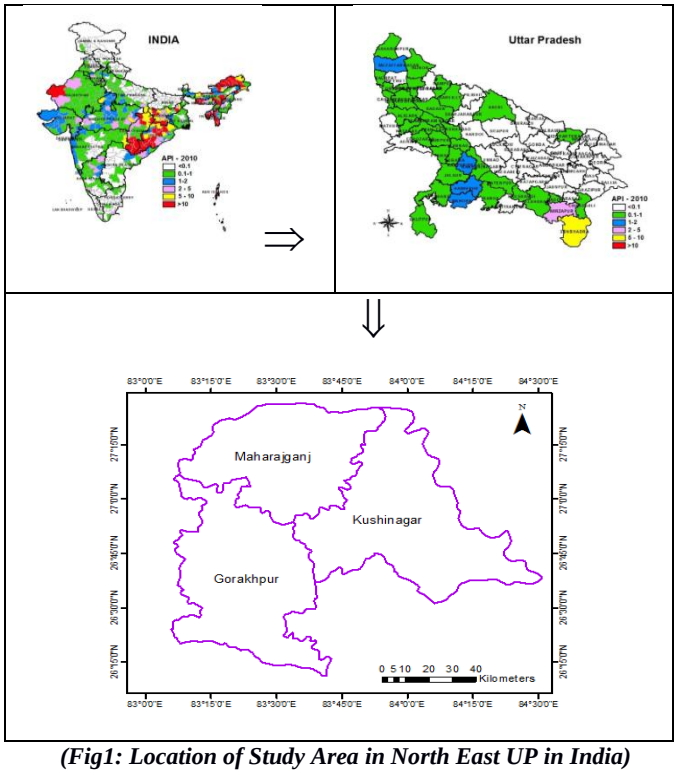
Malariologists working in the field in the first half of this century, in the decades following the elucidation of the malaria cycle in man and mosquitoes, appreciated that it was a focal disease and that the topography of the land was an important consideration in understanding the local epidemiological situation [15].

The Malaria endemicity is primarily because of the development of drug resistance of malarial parasites. It may have various other reasons including ongoing urban developmental activities, indiscriminate use of pesticides, excessive deforestation [13], demographic shifts etc for this enhanced rate of spreading of this disease. Factors further have been linked to the life style of different community [16] (especially for the tribal's), and the behaviour of mosquitoes which transmits the disease as well as climatic and other attributes.

For spreading of mosquito borne diseases factors like proportion of infectious mosquitoes, vector population density, infecting rates after biting, nearness to breeding ground and seasonability, climatic factors, particularly rainfall, temperature and relative humidity are known to have a strong influence on the biology of mosquitoes. To establish these trivial facts, seasonal variation, annual variation and GIS mapping has been done [14]. The entire sets of new observation are in fine correlation with existing reasons behind malaria endemicity. The socio-economic and physic-chemical factors could also be one important cause of malaria endemicity of the study region.

III. STUDY AREA

The three districts Gorakhpur (Lat. 26°13′N to 27°29′N and Long. 83°05′E to 83°56′E), Kushinagar (Lat. 26°39′N to 27°15′N and Long. 83°38′E to 84°15′E) and Maharajganj (Lat. 26°59′N to 27°19′N and Long. 83°09′E to 83°45′E) of eastern Uttar Pradesh has total area of 9291 Sq Km (3.82 % of the state). It lies in the north-eastern corner of the most populous state and comprises a large stretch lying to the north of the river Rapti tributary to the Gandak River and also surrounded by Rohini Rivers at northern side which is the major source of water for the study area.



(Fig1: Location of Study Area in North East UP in India)

It is 275 Km far from the state capital Lucknow and it also makes a joint with International border of Nepal. The study area is one among highly dense region of UP state (Average density around 1210 people per Sq Km: Census 2011) and is home to more than 10.67 million Indian people [4].

IV. GIS APPLICATION AND EPIDEMIOLOGY

GIS can be used to investigate associations between such environmental variables and the distribution of the different species responsible for malaria transmission. In the current work different maps were prepared with help of GIS as tool [2, 3, 12]. Further, based on the data collected from respective district malaria office (DMO) various epidemiological indices can be integrated with GIS findings to obtain cumulative understanding of malaria to find out the prominent reasons for establishing a better malaria control measure and implementation of governmental scheme of malaria control. Further, the inferences drawn from this integrated application can be used by NVBDCP to guide governmental organization at later stage.

V. METHODS

(I). At GIS Level:

It involves following steps:

1. The data related to this work has been acquired from Landsat Thematic Mapper in addition to the epidemiological data collected from district malaria office of the study area.
2. Through ArcGIS 10.1 these set of information were used to develop maps. The analysis was done using ArcView GIS to describe primary risk factors associated with the Malaria endemicity.
3. Points are generated for each PHC/CHC location having its API information.
4. Spatial and attributed data are linked together using ArcGIS.
5. The API values of year 2012 & 2013 are interpolated using IDW (Inverse Distance Weightage) method to map vulnerable zones in the study area.
6. FCC (False Colour Composite) imagery (MIR-Red, NIR-Green and Green-Blue) has been used to locate general landuse in the study area.

(II): Epidemiological Analysis:

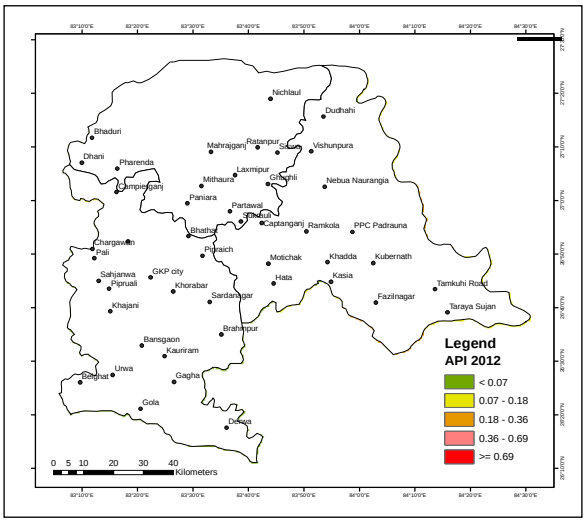
Four epidemiological indices [8] namely 1. ABER (Annual Blood Examination Rate) = (Total number of smears examined in a year/ Total population of the study area) X 100, 2. API (Annual Parasitic Index)= (Total no of cases positive for infection/Population size) x 1000, 3. SPR (Slide Positivity Rate) = (Total Positive cases/ Total number of slides examined) X100 and 4. SFR (Slide Falciparum Rate) = (Total Positive cases for P.*falciparum* Total number of slides examined) X100; have been done for the study area and various interesting observation were made. To develop a comparative analysis of annual variation of indices ABER, API & SPR together, it is difficult to analyse all on same co-ordinate system and hence to establish relative variation, plotting has been done for ABER, 100 x API and 100 x SPR. This change presents a better picture towards establishing how ABER, API and SPR are inter-related.

VI. RESULT

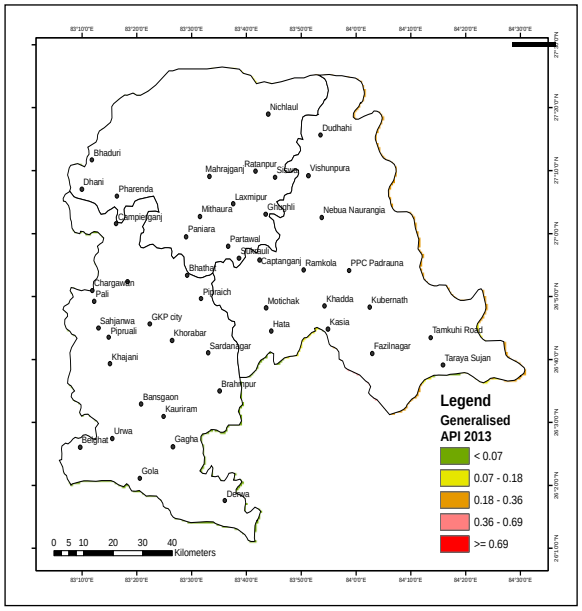
The obtained result can be represented through following GIS maps and tables.

(1) GIS Based Study:

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

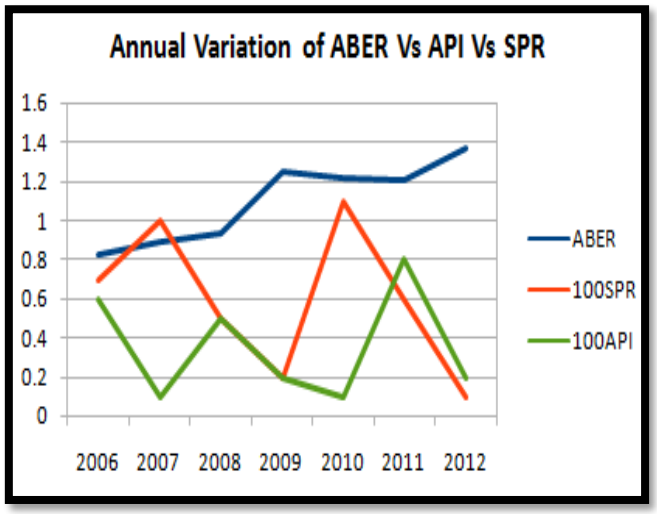


(Fig2: GIS Map with API Data for year 2012)

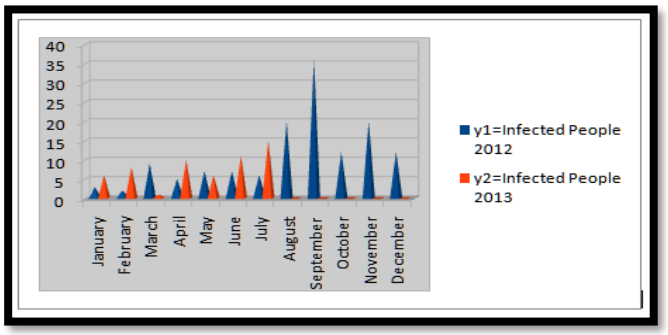


(Fig3: GIS Map with Generalised API Data - year 2013)

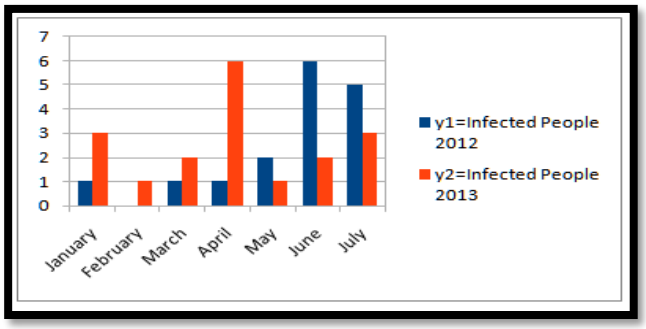
(2) Epidemiological study:



(Graph 1: Annual Variation of ABER Vs 100SPR Vs 100 API for Gorakhpur District)



(Graph 2: Seasonal Variation of API for Kushinagar District)



(Graph 3: Seasonal Variation of API for Maharajganj District)

VII. DISCUSSION

Harnessing the GIS based technology is not new in India. It has been severally implemented to account regions for Malaria risk factors in terms of High risk zone, moderate and low risk zones [13].

Based on GIS maps it can be inferred that:

1. Kubernath region of Kushinagar and Phrenda region of Maharajganj are most vulnerable regions for malaria epidemic during 2012 and based on generalised API for 2013, it is obtained that there is a zonal drift to new regions of Fazilnagar, Ramkola & Captanganj of Kushinagar district, while for Phrenda region there is improvement in API index indication that control measure are implemented satisfactorily.
2. It is also obtained that malaria cases are more among rural masses that urban indicating socio-economic divide and poor treatment measures in remote and village areas.
3. It is maximum in the regions which are sandwiched between two forest regions.
4. Measure of malaria incidence in a community Depends on ABER. Reflect the efficiency & adequacy of case detection mechanism. It is index of operational efficiency. A minimum ABER of 10% of the population/year was fixed under MPO and API < 1.3 under 10th five year plan of Govt of India. API is a sophisticated measure of malaria incidence in a community. It is based on intensive active and passive surveillance, and cases are confirmed by blood examinations. Areas with API ≥ 2 per 1000 population per year have been classified as high risk areas in India, and thereby eligible for vector control.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

5. Interestingly, Eastern UP region was found to have SFR zero unlike the cases of North-East Indian states including Odisha where SFR makes significant presence.
6. The SPR has been used as a surrogate measure of malaria incidence. It provides an alternative method for estimating temporal changes in malaria incidence. Compared to clinical definitions of malaria, the SPR gains accuracy in considering only laboratory confirmed cases of malaria, and it can provide a rapid and inexpensive means of assessing the burden of malaria in a population utilizing health care facilities [6]. Changes in SPR provided a useful estimate of changes in the incidence of malaria.
7. The most interesting observation is that the study region is negative for Plasmodium *falciparum* while it is positive for Plasmodium *vivax*. There was no case reported positive for Pf infection from the region during 2012-13.

Further, it is generally observed that API is much less than one and in these cases it becomes insignificant and hence a new index corresponding to API namely MPPM (Malaria People Per Million) can considered to enhance the level of comparison for study at microscopic level. It is very likely that in times to come MPPM will replace API for study of area where malaria epidemic is in infant stage and we with to analyse it at microscopic level.

VIII. CONCLUSION

The GIS based analysis and malaria hotspots identification techniques in this study can be used at local level also and can be integrated towards developing a website for easy retrieval of the data for better malarial control and implementation of governmental schemes. ArcGIS 10.1 based study was carried out in the study area of Eastern Uttar Pradesh for identification of endemiological risk factors based on Landsat and epidemiological data collected from the district.

If the factors behind Malaria endemicity are exploited and are integrated with Risk factor maps obtained at the result; it will prove to be very much effective for decision making if these are organized and managed properly. The goal of effective Malaria control measures can be accomplished by introducing GIS for analysis and management. A focussed intervention based on the factors may be and should be initiated to Eastern Uttar Pradesh regions to control Malaria transmission and infection.

From the study example; it can be inferred that there is a wide spectrum of possibilities over which GIS can be attributed to Malaria control measures. Its application as an operational planning aid is an extension of geographical reconnaissance to promote better program management at both the state and national levels. Its use as an evaluation tool provides an additional means of spatially analysing outputs generated by health information systems in graphic formats. This can be used as an alternate to the *in Vitro* existing methods and as a cost effective method especially In a developing country like India.

Malaria is a complex disease and its distribution and intensity vary from place to place. Stratification of the problem has become an essential feature for the planning and development of a sound control strategy to maximize the utilization of available resources. It can also provide guidelines as to which strategy could be most suited and economical under the existing conditions.

IX. FUTURE WORK

The utility of GIS as a malaria research tool is inevitable aim of the research institutions a across the globe. The product of this research work would lead to further insights in to Malaria Epidemiology and complexity of its transmission potential in endemic regions.

The map generated can be integrated with Socio-Economic factors and Physico-Chemical effects in addition to the vector density and vector breeding sites to provide excellent model for the Malaria disease management.

Similar Epidemiology integrated with GIS based study using epidemicity maps of NVBDCP should be done for areas of highest national API of regions of Dantewada, Baster & Bijjapur of Chhattisgarh; Kalahandi, Keonjhar & Kandhamal of Odisha; Jaisalmer region of Rajasthan and Lohit region of Arunachal Pradesh to develop national action plan for malaria control measures.

ACKNOWLEDGMENT

Authors are highly indebted to the CSIR for providing the SRF which kept high motivation though out the work. We would like to acknowledge the computer laboratory facility at School of Computational & Integrative Sciences Jawaharlal Nehru University (SCIS, JNU) New Delhi, India. Further, we would like to thank Mr Rajneesh Verma of MapInfo for providing valuable inputs on maps of study area.

REFERENCES

[1] Annjaan Daasha, Aruna Srivastavab, B.N. Nagpalb, Rekha Saxenab & Sanjeev Kumar Gupta, Geographical information system (GIS) in decision support to control malaria – a case study of Koraput district in Orissa, India, J Vector Borne Dis 46, March 2009, pp. 72–74.

[2] Booman M, Durrheim DN, La Grange K, Martin C, Mabuza AM, Zitha A, Mbokazi FM, Fraser C, Sharp BL. Using a geographical information system to plan a malaria control programme in South Africa. Bull World Health Organ 2000;78:1438e44.

[3] Briet OJT, Gunawardena DM, Van Der Hoek W, Amerasinghe FP. Sri Lanka malaria maps. Malar J 2003;2:22.

[4] Census of India 2011: From Uttar Pradesh Administrative atlas. Directorate of Census Operations Uttar Pradesh.

[5] Daash A, Srivastava A, Nagpal BN, Saxena R, Gupta SK. Geographical information system (GIS) in decision support to control malaria e a case study of Koraput district in Orissa, India. J Vector Borne Dis 2009;46:72e4.

[6] Joshi PL, Chandra R, Bhattacharya M, Vaish HC: Validity of using Slide Positivity Rate (SPR) in identification of high risk malarious segment in rural areas. The Journal of communicable diseases 1997, **29**(1)**:**41-45

[7] Malaria situation in India. Delhi: National Vector Borne Disease Control Programme, Ministry of Health and Family Welfare, Govt. of India. Available from: http://www.nvbdcp.gov.in/Doc/malaria1.pdf

[8] Park, K Textbook of Preventive and Social Medicine, 22nd Ed, 234-35, 248.

[9] Shyam Avtar Agarwal, Shailendra Singh Sikarwar1 and D.Sukumaran, Application of RS & GIS in Risk area assessment for mosquito borne diseases- A case study in a part of Gwalior City (M.P.), IJATER 2(1), Jan-2012.

[10] Singh N, Mishra AK, Shukla MM, Chand SK. Forest malaria in Chhindwara, Madhya Pradesh (central India), A case study in ethnic tribal community. Am J Trop Med Hyg 2003; 68: 602–7.

[11] Srivastava A, Nagpal BN, Joshi PL, Paliwal JC, Dash AP. Identification of malaria hot spots for focused intervention in tribal state of India: a GIS based approach. Int J Health Geog 2009;8:30.
[12] Srivastava A, Nagpal BN, Saxena R, Sharma VP. Geographical information system as a tool to study malaria receptivity in Nadiad Taluka, Kheda district, Gujarat, India. Southeast Asian J Trop Med Pub Health 1999; 30: 4.
[13] Srivastava A, Nagpal BN, Saxena R, Subbarao SK. Predicted habitat modeling for forest malaria vector species An. dirus in India e a GIS based approach. Curr Sci 2001;80:1129e34.
[14] Srivastava A, Nagpal BN, Saxena R, Wadhwa TC, Mohan S, Siroha GP, Prasad J, Subbarao SK. Malaria epidemicity of Mewat region, district Gurgaon, Haryana, India: a GIS based study. Curr Sci 2004;86:1297e303.
[15] Sweeny A.W. The Application of GIS in Malaria Control Programs, 10th Colloquium of the Spatial Information Research Centre, 1998, 315-20.
[16] Tribal malaria. ICMR Bull 2004; 34(1): 1–10. Available from: http://icmr.nic.in/BUJAN04.pdf
[17] World Health Organization, World malaria report 2009. Geneva, Available from: http://www. who.int/malaria/wmr2008.pdf
[18] Yadav K, Nath MJ, Talukdar PK, Saikia PK, Baruah I, Singh L. Malaria risk areas of Udalguri district of Assam, India: a GIS based study. Int J Geogr Inf Sci 2012;26:123e31.

Abdul Qayum has done his Bachelor of Technology in Civil Engineering from Indian Institute of Technology, Kanpur (IITK). He has done his B.Tech project on "Utility mapping using GPR- Ground Penetrating Radar". Currently he is working as Senior Research Fellow (SRF, CSIR) on "GIS Based Traditional Knowledge Mapping of Natural resources towards identifying anti-malarials" under guidance of Dr Andrew M Lynn at Center for Biology & Bioinformatics, School of Computational and Integrative Sciences, Jawaharlal Nehru University (JNU) New Delhi. He holds CSIR-JRF award in Chemical Science with All India Ranks 40 & 67. He has great interest in "Malariolgy mapping of areas and medicinal plants" and heading towards submitting his PhD work. Recently, he went to London for oral presentation for an International Conference on Secured Transaction ICITST-2012 and has published his paper in IEEE Xplore. He is a member at IEEE Delhi Division. He can be reached for any collaboration work and sharing ideas at: qayum.iitk@gmail.com.

Dr. Andrew M Lynn is Associate Professor at School of Computational and Integrative Sciences, Jawaharlal Nehru University (JNU) New Delhi. He is director of communication and Information Services CIS , JNU and holds many key positions in the university. He has guided dozens of M.Tech and PhD students. He is principal investigator of many projects including one CSIR, project of Open Source Drug Discovery. He is successfully running on his laboratory and his works are related to mainly computational biology and High performance computing. He can be contacted at:
http://www.jnu.ac.in/Faculty/andrew/

Dr. Rakesh Arya is Ph.D. on "Environmental & Anthropogenic Impact on Landscape Evolution" from Centre for the Study of Regional Development (JNU, New Delhi) along with Masters and M.Phil. He is well versed in applying spatial technologies in solving real world problems. He is bachelor in Anthropology and Travel and Tourism Management and holds CSIR-JRF in Earth Sciences. Apart from GIS and Remote Sensing application, he is exceedingly good in climatological modelling (WRF) and DHI Mike hydrological simulations. He can be reached for any collaboration at:
aryarakesh.mnu@gmail.com

Dr. Sanjay Kumar Jaiswal has done his Bachelor of Medicine and Bachelor of Surgery from Motilal Nehru Medical College Allahabad, affiliated to Erstwhile King George's Medical University UP Lucknow. Currently he is working as Medical Officer In charge at Community Health Center Seorahi, Kushinagar, Uttar Pradesh. He has also qulified AIPGMEE with AIR 9699 and opted M.D. Microbiology in Vijaynagar Institute of Medical Sciences Bellary, Karnatka. He is a member of UP Medical council and UP Provincial Medical Services. He also attended a Training Programme on Routine Immunization at Regional Health and Family Welfare Training Center (B.R.D. Medical College) Gorakhpur, Uttar Pradesh (sanjay.knmc@gmail.com)

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)