Introduction
CHAPTER I: INTRODUCTION

1.1. Malaria problem

Malaria is among most common vector borne diseases pervasive in the tropical and subtropical regions. Although substantial success of malaria control programmes was attained in the past, malaria still continues as a major public health problem in several countries. It is one of the top listed diseases as mentioned in the world health organization (WHO) report, risking 3.3 billion people in 106 countries with 216 million cases and nearly 6, 55,000 deaths annually. About 77% of the total victims are children under 5 years of age, and 90% of malaria deaths occur in the African region (WHO, 2013a). India ranks second in terms of occurrence of malaria in the world and spatial malaria trend here reveals varying level of endemicity (Srivastava et al., 2006). With two third of the all confirmed malaria cases in the entire south east Asia region, India reports 1.5 million malaria cases annually (WHO, 2010).

Fig. 1.1 Malaria endemic zones of south Asia (Source: Kumar et al., 2012)
The north-eastern states of India are highly endemic for malaria incidence and several deaths are reported annually (Das et al., 2004; WHO, 2010). *Plasmodium falciparum* contributes majority of the malaria cases, whereas the remaining are mainly attributed to *P. vivax* infection (Dev et al., 2001; Dev et al., 2004; Dhiman et al., 2011; Rabha et al., 2011). Many efficient and highly anthropophilic malaria vectors, such as *Anopheles dirus*, *An. minimus* and *An. fluviatilis* aggravate the malaria situation in the region (Dhiman et al., 2010a; O'loughlin et al., 2008).

The state of Assam is most populated (27.85 million) and area-wise second largest (78,523 km²) in the entire north-eastern region of India. This state alone has been reported to contribute >5% malaria cases and 20% of all the malaria attributable deaths reported in India annually (Prasad, 2009). The region is endowed with rich biodiversity associated with heavy rainfall (2-3 meters) and malaria receptivity is high with estimated 30-40% population at high risk (Dev et al., 2006b). About 40% of the land area is under forest cover and large tracts are flood prone zones render that area inaccessible to the health workers. The poorly clothed tribals scattered in the foot hills and forest, availability of inadequate health infrastructure, increasing spread of antimalarial drug resistance and low socio-economic status of population are some of the factors that maintain malaria as an important public health problem in this region (Dhiman et al., 2010b). One hundred three out of 156 primary health centers in Assam have been identified as malaria high risk zones on the basis of selected epidemiological criteria (Dev et al., 2004). The areas sharing interstate and international border are at a greater risk of focal outbreaks due to various conducive reasons and lack of well planned and coordinated vector control operations (Dhiman et al., 2010a, b). Despite of the comprehensive malaria control measures by national vector borne diseases control
programme (NVBDCP), malaria persists as a leading public health problem in this region and the transmission keeps going on uninterrupted (NVBDCP, 2009).

1.2. Socio-economic factors and malaria

Malaria has been frequently linked with poverty and has a devastating socio-economic impact on affected countries, majority of which are developing, poor and located in the tropics. Poverty has been found to be concentrated in the tropical and subtropical zones sharing same geographical boundaries that closely frame the malaria transmission. Living in the malaria endemic regions tends to exert an economic burden on the households even if they do not actually suffer from malaria (Laxminaraynan, 2004). Reports suggest that reducing the disease prevalence in these areas significantly improves the household’s living standards (Laxminaraynan, 2004). Malaria causes extensive premature deaths and suffering which imposes financial hardship, and holds back economic development. Malaria flourishes more in social and ecological crisis, weak health systems which disadvantaged communities (WHO, 2000). It has been found that the incidence of malaria is comparatively lower in urban than the rural settings. Residents of urban areas have potentially protective variables, such as education, income, good environment and easy access to the health facility, which provide considerable protection against malaria risk (Worrall et al., 2005). There may be a relationship between prevention of malaria and its incidence because members of the poor socio-economic groups are not able to afford sufficient insecticide treated nets and live in more vulnerable dwellings that offer little protection against mosquitoes. Socio-economic factors are clearly related to the health risks and now it has been well established that morbidity and mortality rates are directly associated with socio-economic status of the population (Dhiman, 2009). The World Bank, WHO, and other
international agencies, while maintaining that the good health is a human right, are also arguing that “investing in health” is crucial because improved health has been seen as a prerequisite for sustainable development (WHO, 2013a). It is well recognized that the reduction of malaria is a social good in itself and therefore comprise of an important element which is related to the overall social development process. Human behavior, an often under recognized factor in malaria transmission has been reported one of the important factor impacting malaria in many endemic areas (Dhiman, 2009). Another considerable risk factor is the movement of people to and from the forested areas, primarily related to socio-economic as well as socio-cultural reasons, has been found to increase the malaria vulnerability (Panvisavas, 2001; Panvisavas et al., 2001). For example, in Cambodia, inhabitants living in the forest fringed areas frequently make overnight visits into the forest for hunting or to collect wood to earn livelihood. Furthermore, temporary migrants, such as, loggers, sandalwood collectors, soldiers and gem miners also visit the forest during night without personal protection, thereby frequently exposed to the mosquito bites (Dysoley et al., 2008). In Indian, tribals in central parts often visit the forests at night time to collect “Mahua” (Madhuca indica) flowers for making country liquor and get bitten by the vector mosquitoes (Singh et al. 2004). In Madhya Pradesh state of central India, the falciparum malaria was first reported in Panna district, which gradually spread into the other areas of the state owing to various socio-economic and cultural determinants (Singh et al. 2004). Other factors related to human behavior such as, not using insecticide treated nets (ITNs) at night and reluctant in taking antimalarial chemotherapy also compound malaria transmission (Cai et al., 1995; Roosihermatie et al., 2000). This type of behavior primarily arise from the lack of awareness and knowledge about malaria prevention and transmission, as shown
in Lao, where the level of malaria prevention was significantly correlated with the level of education among the people living in malaria endemic areas (Uza et al., 2002). In Thailand, the use of bed nets for preventing malaria in children was higher amongst mothers who had a better knowledge of the disease and its components (Sri-aroon et al., 1998). In north-east India, disease distribution is geographically restricted but remains largely entrenched among the population groups living in poverty particularly in the foothills villages. In Assam, majority of the vulnerable population is engaged in tea cultivation and lives below the poverty line constituting a big driver for maintaining perennial malaria transmission without interruption (Rabha et al., 2011). The state comprised of 12.8 % and 7.4 % schedule tribes and scheduled castes respectively (Sharma, 2003), majority of which are suffering from geo-political neglect, high level of poverty and believe in ethnic culture and traditional systems of disease treatment (Chaturvedi et al., 2009).

1.3. Insecticide resistance in vector control

Vector control has globally played an important role in the reduction of malaria. In India, mosquito vector control mostly depends on indoor residual spraying (IRS) of dichlorodiphenyltrichloroethane (DDT), malathion or synthetic pyrethroids in rural areas and breeding source reduction including anti-larval measures using suitable insecticide in the urban settings (Dhiman et al., 2013). In the past, DDT was used throughout the world for large area mosquito control, but now banned in most of the developed countries due to many adverse effects (Dash et al., 2007a). Controversially, DDT remains in common use in many developing countries still struggling to control mosquito vectors using limited resources, which argue that the cost of switching to other insecticides and control methods would exceed the harm caused by using DDT.
Now it is approved for use only in specific and limited conditions, where it could be most effective against the vector mosquitoes. During last two decades, various synthetic pyrethroids, such as deltamethrin, cyfluthrin and lambdacyhalothrin have been introduced into the public health programmes as residual insecticides and for impregnation of mosquito nets (Dash et al., 2007b). Many commercial formulations of synthetic pyrethroids based insecticides are available at affordable prices, which have been found to perform better than other insecticide classes in terms of safety, durability and efficacy (GPIRM, 2012). In 2009, pyrethroids were estimated to account for about 75% of total IRS coverage, whereas DDT was the second most widely used insecticide for malaria vector control interventions (GPIRM, 2012). The importance of effective mosquito vector control and the reliance on a limited number of insecticides, preserving the susceptibility of malaria vectors to pyrethroids and to the other three classes of insecticides is very crucial in order to maintain effective malaria control using insecticides. The development, spread and evolution of insecticide resistance against commonly used insecticides could jeopardize current and future gains achieved in malaria control efforts (Dhiman et al., 2013).

In India, at least five major malaria vectors exist as species complexes of several sibling species, which have a considerable impact on their susceptibility to recommended insecticides in public health programmes (Subbarao et al., 1988). *An. stephensi* has been found triple resistant against the DDT and hexachlorocyclohexane (HCH), as well as malathion, whereas *An. culicifacies* has been shown to exhibit quadruple resistance, including all the above as well as to deltamethrin (Mittal et al., 2002; Singh et al., 2002). The resistance to deltamethrin is a cause for concern from a public health perspective as synthetic pyrethroids are currently recommended and
preferred choice for ITNs as well as for IRS in many endemic areas. *An. culicifacies* has been documented to be resistant to DDT in 286 districts and to DDT and malathion both in 182 districts in India (Dash *et al.*, 2006), although the actual figures could actually be much higher as the data from many endemic areas is either limited or not available. The HCH was banned in India in 1997 due to resistance as well as environmental concerns, while DDT is still being used selectively for malaria and kala-azar vector control. One of the major reason for resurgence of malaria in India in the mid-1970s was insecticide resistance in malaria vectors (Sharma, 1984), which indicated that there is an urgent need for monitoring and controlling development of insecticide resistance in the mosquito vectors at local level.

The knowledge of vector resistance and changing trends of resistance in target species are basic requirements to guide insecticide use in malaria control programmes. Beside these, the lack in surveillance activity, inadequate laboratory facilities and services, poor reporting of malaria cases and un-planned control activities are additional factors supporting the malaria outbreaks in the recent years (Dhiman *et al.*, 2011; Nath *et al.*, 2013) Since insecticide resistance is a dynamic phenomenon and its level varies from region to region, the decision on the selection of insecticide needs to be ideally taken at regional levels. To tackle the problem of development of insecticide resistance a network need to be set up for the monitoring of real-time insecticide resistance in order to assess the insecticide resistance status of malaria vectors in different areas. Further, the trend in resistance status should be carefully monitored and the impact of existing vector control tools on resistant population should be assessed.
1.4. Role of geographical information system (GIS) in monitoring malaria and mosquitoes

The knowledge of geographical distribution of disease is important to monitor the control programme. The GIS technique has been used widely to identify the main ambiguities and problems for better implementation in various disease management projects. GIS applications are useful in better and effective visualizing and analyzing disease data, revealing trends, dependencies and inter-relationships existent among the complex variables.

*GIS can help in disease management by following important points.....*

1. Optimizing data collection and management
2. Strengthening data analysis
3. Strengthening outbreak infrastructure and support
4. Map epidemic in near real time
5. Quickly plan and target responses
6. Rapidly communicate information
7. Monitor changes in disease over time
8. Plan and monitor intervention and eradication programs
9. Aid emergency preparedness by mapping surveillance data in near real time for early outbreak detection

In the last few years, GIS has drawn considerable attention in understanding and visualizing the current status of emerging and re-emerging infectious diseases (Ceccato *et al.*, 2005; Kobayashi *et al.*, 2001; Nath *et al.*, 2012; Srivastava *et al.*, 2004; Yadav *et al.*, 2012). In India GIS was utilized for identification of hotspots and visualization of spatial changes in malaria hotspots of Madhya Pradesh (Srivastava *et al.*, 2009), Assam
(Nath et al., 2013; Yadav et al. 2012), Jharkhand (Saxena et al., 2012) and Tamilnadu (Kumar et al., 2014). These studies have highlighted the utility of GIS and spatial statistical tools in efficient processing of voluminous epidemiological data and analyzing with statistical base for guiding the control operations. These studies have established the role of GIS in disease control by providing rapid and readily understandable results which are required for quick decision-making. In Zambia, GIS based decision support system was used to collate data on insecticide resistance in which the spatio-temporal insecticide resistance profiles of major malaria vectors An. gambiae s.s., An. arabiensis, and An. funestus were determined at certain places and later extended to other regions of the country by standard WHO protocol (Chanda et al., 2012). The visual GIS maps guided the malaria control programme authority to better utilize the limited resources on selected insecticides to which the malaria vectors are still susceptible. Detection of high resistance levels has facilitated the planning of rational insecticide resistance management strategies and the introduction of alternative non-insecticide based vector control interventions (Chanda et al., 2012).

Public health practice needs timely information on the course of disease and control events to implement appropriate actions and GIS is an innovative technology for generating and communicating this type of information. The GIS based malaria incidence mapping has been used extensively for risk assessment at national, regional, town and village level. Such mapping is considered important for analyzing past as well as present disease trends. The risk maps developed on the basis of mapped malaria incidences are useful as guiding tools for targeted and cost-effective control measures in an area of interest.
1.5. Aim and objectives of the study

1.5.1. Aim of the study

The aim of the present investigation is to study the geographical distribution of malaria in Udalguri and Sonitpur districts of Assam at health sub-centre (SC) level from the year 2006 to 2010 and to prepare GIS based maps to visualize and highlight the disease hotspots based on past and present data. The study also emphasizes the prevalence of anophelines vectors, their insecticide resistance status against commonly used insecticides and also the association of socio-economic variables with malaria prevalence in potential malaria hotspots identified in the current study.

1.5.2. Objectives

1. To analyse the spatio-temporal distribution of malaria incidence in Udalguri and Sonitpur districts.

2. To provide baseline data on the distribution of mosquitoes in the selected areas of the study area.

3. To assess the insecticide resistance status in *Anopheles* mosquitoes in the study area using standard methodology.

4. To analyse the relationship between socio-economic factors and malaria risk.