



National Institute of Malaria Research-Malaria Dashboard (NIMR-MDB): A digital platform for analysis and visualization of epidemiological data

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Summary

Background A digital dashboard can be an invaluable resource for the research community and can help analyze and visualize data as per the inputs provided by the user. In India, large data sets on malaria are available though presently no digital dashboard is being used to monitor and analyze the malaria data.

Methods We have developed a dashboard (National Institute of Malaria Research-Malaria Dashboard (NIMR-MDB)) in R software using 19 different packages within which shiny and ggplot2 are used more intensively. NIMR-MDB can be used offline by running the app on any R software installed computer. Furthermore, NIMR-MDB can be accessed across different computers within an organization using a local server, or it may be made publicly available by publishing it online with secured access. There are two options for publishing the shiny dashboard online 1) via a personal Linux server for hosting this application or 2) by hosting the application on a certified online platform such as 'shinyapps.io' at a reasonable cost without setting up a server.

Findings The NIMR-MDB is a versatile interface that allows prompt and interactive analyses of malaria epidemiological data. The primary interface of NIMR-MDB is like a web page with 14 tabs (or pages) where each Tab corresponds to a particular set of analysis. Users may move from one Tab to another via icons. Each Tab allows flexibility in correlating various epidemiological parameters like SPR, API, AFI, ABER, RT, malaria cases, deaths, BSC and BSE. The malaria epidemiological data can be analyzed in the required granularity (national level, state level or district level), and its enhanced visualization allows for facile usage and extensive analysis.

Interpretation This NIMR-MDB developed here will play an important role in the analysis of epidemiological data and in strategizing malaria control in India. Researchers and policymakers may use it as a prototype for developing other dashboards for various diseases globally.

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Keywords: NIMR; Malaria dashboard; Malaria epidemiology data; NIMR-MDB; MDB

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Abbreviations: NIMR-, National Institute of Malaria Research; API-, Annual Parasite Incidence; AFI-, Annual Falciparum Incidence; SPR-, Slide Positivity Rate; ABER-, Annual Blood Examination Rate; RT-, Radical Treatment; BSC-, Blood Smears collected; BSE-, Blood Smears Examined; Pf-, *Plasmodium falciparum*; Pv-, *Plasmodium vivax*; Total-, Total malaria cases

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Introduction

Malaria is a significant public health problem in India and ~90% of its population is at risk. The Directorate of the National Centre for Vector Borne Diseases Control (NCVBDC) is the central nodal agency for preventing and controlling six vector-borne diseases including malaria.¹ The NCVBDC has been collecting/recording malaria data on various parameters for several decades.² This is one of the most extensive data sets on malaria and its ready analysis is vital for constant monitoring of the malaria situation in India. The variability and heterogeneity in malaria parameters in a vast country like

Research in context

Evidence before this study

National Centre for Vector Borne Diseases Control (NCVBDC) is responsible for collecting malaria data in India. This is one of the most extensive data sets on malaria, and its quick and granular analysis is highly desirable for malaria control activities across India.

Added value of this study

We have developed a dashboard that integrates and presents malaria data of NCVBDC in an intuitive and flexible format of graphs, tables and maps that allow immediate visual analysis in just a fraction of time.

Implications of all the available evidence

MDB may help in monitoring and analysis of malaria epidemiological data and could work as a tool for the malaria elimination programme in India.

India requires a highly granular approach for analyzing malaria incidence and planning appropriate interventional tools. Understanding the malaria-metric data of a particular region is a prerequisite for effectively designing any operational study. The epidemiological data are also valuable for (a) calculation of appropriate sample size, (b) finalizing the duration of any study, (c) determining the transmission periods, (d) and for identifying the dominant malaria parasite species, amongst others. Although NCVBDC’s malaria data are rich, their analysis can be tedious. For example, if one is interested in analyzing the Annual Parasite Incidence (API) of a particular district in India over ten years, one would need to extract the information from ten excel files (one file for each year in the present scenario). The process might become more cumbersome if the user intends to compare the data between several districts as India has >720 districts. Therefore, an efficient tool for analyzing malaria data is needed and a digital dashboard can effectively solve the above-mentioned problems.^{3–5} As witnessed during the COVID-19 pandemic, many interactive dashboards,^{6–9} including one from our group,¹⁰ were developed and these helped in tracking the COVID-19 pandemic. A digital dashboard is handy in all situations where continuous data are being generated and close monitoring is required to develop effective strategies.

We have developed a dashboard (National Institute of Malaria Research-Malaria Dashboard (NIMR-MDB)) that addresses all the problems mentioned above and makes it facile to access and analyze epidemiological data. The NIMR-MDB integrates and presents data in an intuitive and flexible format of graphs, tables, and maps that allow an immediate visual analysis of malaria data. The NIMR-MDB can efficiently be utilized and/or co-opted in other countries for malaria or other infectious diseases with some modifications in the existing R code of NIMR-MDB.

Methods

Construction and content

Our previous work discussed the vision behind our dashboard.¹¹ Here we provide details on the construction and content of NIMR-MDB and demonstrate its utility for data analysis. The NIMR-MDB has been developed in R software (version 4.1.3) using shiny as a primary package. R is a powerful language and an apt environment for statistical computing and graphics.¹² R consists of many packages wherein Shiny is popular as it is used for developing web applications.¹³ The Shiny package is free, open-source and is available from GitHub.^{13,14} The Shiny server is a program specifically designed to host any Shiny app as a web page. Shiny apps are contained in a single script called app.R (or any name such as NIMR-MDB.R). The script app.R is stored in a project directory along with all supplementary files. The app.R has two main components: **ui.R** (User Interface) and **server.R** (Server Function). The ‘ui’ is responsible for controlling the layout and appearance of the app and the server function is needed to write the instructions for building the app. Besides Shiny other packages used in the development of NIMR-MDB for various functions are briefly enumerated in the table below.

S.No.	Package Name	Brief Description
1	Shiny ¹⁵	Main package for the development of web application
2	Shinyauthr ¹⁶	Supporting library of shiny used for user authentication
3	shinydashboard ¹⁷	Supporting library of shiny for interactive operation
4	Shinythemes ¹⁸	Supporting library of shiny for choosing different themes
5	shinyWidgets ¹⁹	Supporting library of shiny for developing custom widgets
6	ggplot2 ²⁰	One of the most power packages of R for graphical presentation of data
7	ggrepel ²¹	It is a supporting package of ggplot2
8	ggpubr ²²	It is used for graphical presentation of data
9	Plotly ²³	It is used for graphical presentation of data
10	dplyr ²⁴	Used in data processing
11	DT ²⁵	Used for JavaScript library for data tables
12	stringr ²⁶	It provides a cohesive set of functions for strings
13	RColorBrewer ²⁷	It is used to manage colours
14	Scales ²⁸	It controls the appearance of axis and legend labels
15	Jpeg ²⁹	For reading, writing and displaying the bitman images stored in the JPEG format
16	Viridis ³⁰	Used for color scaling

(Continued)

S.No.	Package Name	Brief Description
17	Tidyverse ³¹	It is also used for color scaling
18	tmap ³²	Used for geographical mapping
19	SF ³³	Used for geographical mapping

R Codes for NIMR-MDB: The R codes for NIMR-MDB are available on GitHub and can be accessed through the following link (<https://github.com/nimrmdb/sdb/blob/main/app.R>)

Online link: NIMR-MDB has not been uploaded on the online server yet due to data protection issues. However, to give a fair idea, the dashboard with simulated (or dummy) data as a 'proof-of-concept' can be accessed through <https://nimrmdb.shinyapps.io/MDBschool/> by using the following credentials:

User Name: school

Password: pass1

Data access and visualization output on the right panel of the web application will be made available to the user upon entering the correct credentials.

Data source

National Centre for Vector-Borne Diseases Control's (NCVBDC) malaria data (yearly) from district to the national level were used as a back-end data source for this dashboard. NCVBDC provided the data to the National Institute of Malaria Research upon request from the Indian Council of Medical Research (ICMR).^{1,34}

Data and data levels

The annual data (from 2000 onwards) of various malaria parameters acquired from the NCVBDC are available at two levels: State (India has 28 states and eight union territories) and district level (>720 districts).

Data variables

NIMR-MDB displays information on 16 malaria indicators. A brief description of the parameters that can be visualized and analyzed on NIMR-MDB is provided below:

- Pop1000:** Population of the district/state in thousands in a particular year
- BSC (Blood Smears Collected):** Blood smears collected in a particular year
- BSE (Blood Smears Examined):** Blood smears examined in a particular year
- API (Annual Parasite Incidence):** The number of confirmed new malaria cases expressed per 1,000

individuals at risk under surveillance.³⁵ It can be written as

$$API = \frac{\text{Total positive}}{\text{Total population}} * 1000$$

- SPR (Slide Positivity Rate):** the number of laboratory-confirmed malaria cases per 100 suspected cases examined. It can be written as

$$SPR = \frac{\text{Total positive}}{\text{Total Blood Slide Examined (BSE)}} * 100$$

- ABER (Annual Blood Examination Rate):** It indicates the number of people receiving a parasitological test for malaria per unit population per year. It can be written as

$$ABER = \frac{\text{Number of slides examined}}{\text{Population}} * 100$$

- AFI (Annual Falciparum Incidence):** The number of confirmed new *Plasmodium falciparum* cases expressed per 1,000 individuals at risk under surveillance. It can be written as

$$AFI = \frac{\text{Total positive for Plasmodium falciparum}}{\text{Total population}} * 1000$$

- Total:** Total Number of malaria cases (*Plasmodium vivax (Pv)*, *Plasmodium falciparum (Pf)* and mixed) in a particular year
- Pv:** Total number of *Plasmodium vivax (Pv)* cases in a particular year
- Pf:** Total number of *Plasmodium falciparum (Pf)* cases in a particular year
- Mixed:** Number of positive cases for *Plasmodium vivax (Pv)* and *Plasmodium falciparum (Pf)* in a particular year
- Pf_per:** Percentage of *Plasmodium falciparum (Pf)* cases among total cases in a particular year
- RT:** Radical treatment (RT) given in a particular year
- Total_death:** Total deaths due to malaria (cases due to *Plasmodium vivax*, *Plasmodium falciparum* and mixed cases) in a particular year
- Pv_death:** Total deaths due to *Plasmodium vivax (Pv)* malaria in a particular year
- Pf_death:** Total deaths due to *Plasmodium falciparum (Pf)* malaria in a particular year

Ethics approval

The study is approved by Institute Ethics Committee (Ref. No: NIMR/ECM/2022/17)

Role of Funding source:None

Results

The primary interface of NIMR-MDB is similar to a web page and it has 14 different Tabs (or pages). Each Tab is

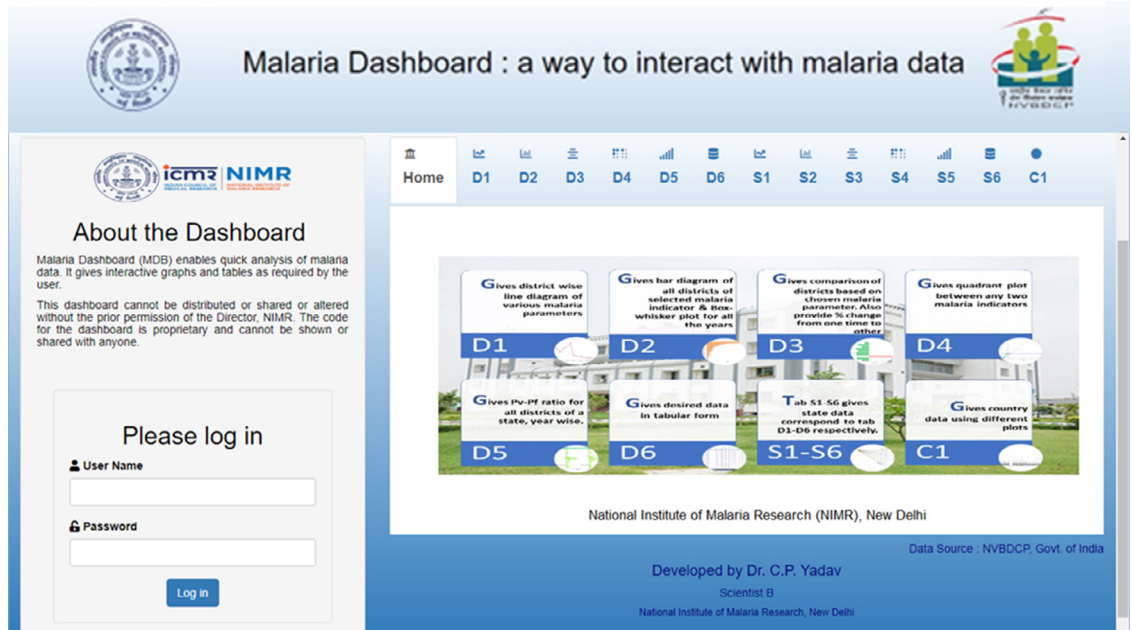


Figure 1. Home tab gives basic information about the dashboard.

independent and specific to a particular set of analysis. Output is presented in interactive tables, graphs, and maps as per the input provided by the user with different drop-down and checkbox options. They are explained below:

Home Tab: The application starts with an introduction of the NIMR-MDB. The right-side panel displays all the Tabs of the dashboard: Tabs D1 to D6 provide

district-level data analysis, Tabs S1 to S6 provide state-level data analysis, and Tab C1 is for country-level data analysis. User authentication is performed on the Home Tab thus restricting unauthorized access. Here a user has to login to the dashboard using pre-approved credentials (Figure 1).

Tab D1: Tab D1 plots the district-level malaria data using a line graph in a time-series manner. This Tab allows users to assess the changes in various malaria

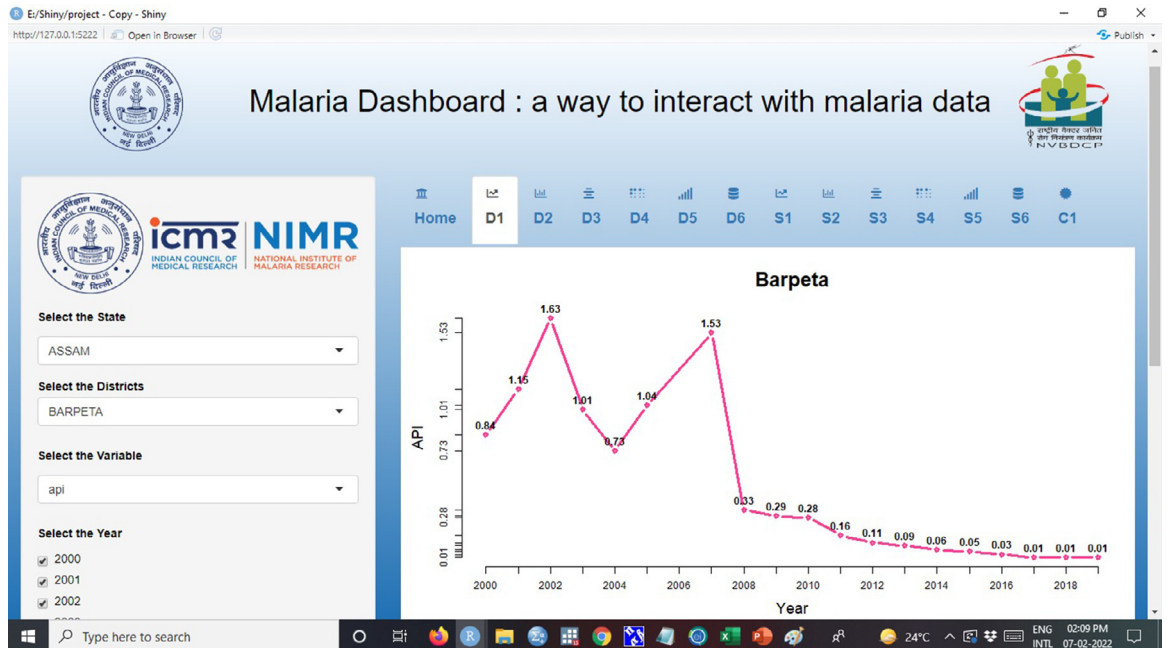


Figure 2. Tab D1 gives time series analysis of various malaria parameters on district-level data.

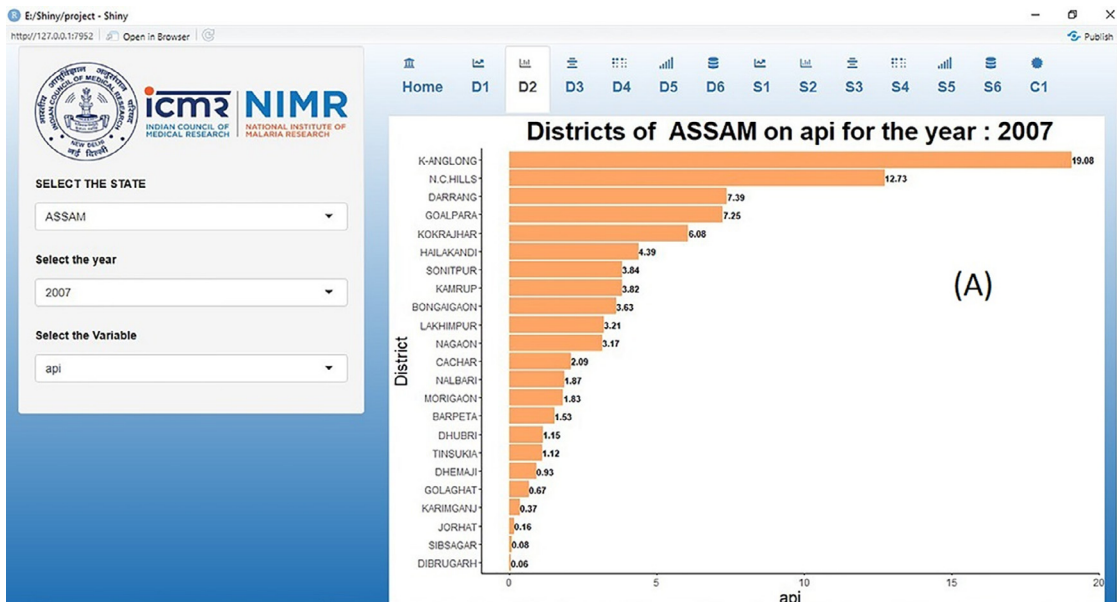


Figure 3. Graph A on tab2 gives descending arrangement of districts of a state based on particular malaria parameter in a particular year.

parameters over time for any district of India, one at a time. Users may select the state (India has 28 states and eight union territories) followed by a district of that state, the malaria parameter, and the time interval using drop-down and check box options on the left-hand panel to get the desired output (Figure 2).

Tab D2: On Tab D2, users are provided with three different graphs that compare and contrast various malaria parameters across all the districts of a selected state. As in the previous Tab, a user can also select multiple options using the drop-down menus provided in the left-hand panel such as the state, year, and the malaria variable of interest. The first graph, displayed on the right-hand panel, is a bar diagram that arranges all the districts of the selected state in descending order of chosen malaria parameter in a particular year (determined by the user). For example, a user may select Assam as a state of interest, 2007 as the year, and API as the malarimetric parameter using the three drop-down menus on the left-hand panel. Then a bar graph of all the districts of Assam, arranged in descending order of API for the year 2007, would be displayed in the right-hand panel (Figure 3). The second graph on this Tab is a Box-Whisker's plot of any given malaria parameter for all the districts of the selected state for all years (say from 2000 to 2019) (Figure 4-A). The third graph on this Tab is a district-level geographical map of the selected state, and it displays the selected malaria parameter in a given year using a graded colors map (Figure 4-B).

Tab D3: On Tab D3, two graphs are displayed to compare malaria parameters across multiple

districts from one or more states in any given time interval. The first graph is similar to the diagram shown in Tab D1, with the added capability of displaying more than one district to compare malaria parameters across any number of districts (Figure 5). The second graph on Tab D3 is a positive-negative bar diagram that displays an increase or decrease (in percentage) in a particular malaria indicator between the two selected years (Figure 6).

Tab D4: Tab D4 allows users to assess the relationship between any two malaria parameters. Along with this, users can perform quadrant analysis (that means, based on any two malaria parameters, a user can divide the districts of a particular state into four quadrants: where x variable is high, and y variable is low (Quadrant 1) or where both are high (Quadrant 2) or where y variable is high, and x variable is low (Quadrant 3) or finally where both the variables are low (Quadrant 4). Thresholds for high and low can be fixed using X center and Y center options. For example, suppose one is interested in the districts where ABER is low (say <10%) and SPR is high (say > 5) - this plot will immediately provide visuals of the same (Figure 7).

Tab D5: The next Tab gives the ratio of *Plasmodium vivax* (Pv) and *Plasmodium falciparum* (Pf) for all the districts of a selected state for one or more years in the form of a left-right bar diagram. This analysis can provide insights such as trends of Pv transmission in areas where Pf transmission has been stemmed. Such a heterogeneous scenario of malaria in the context of prevalent species presents a

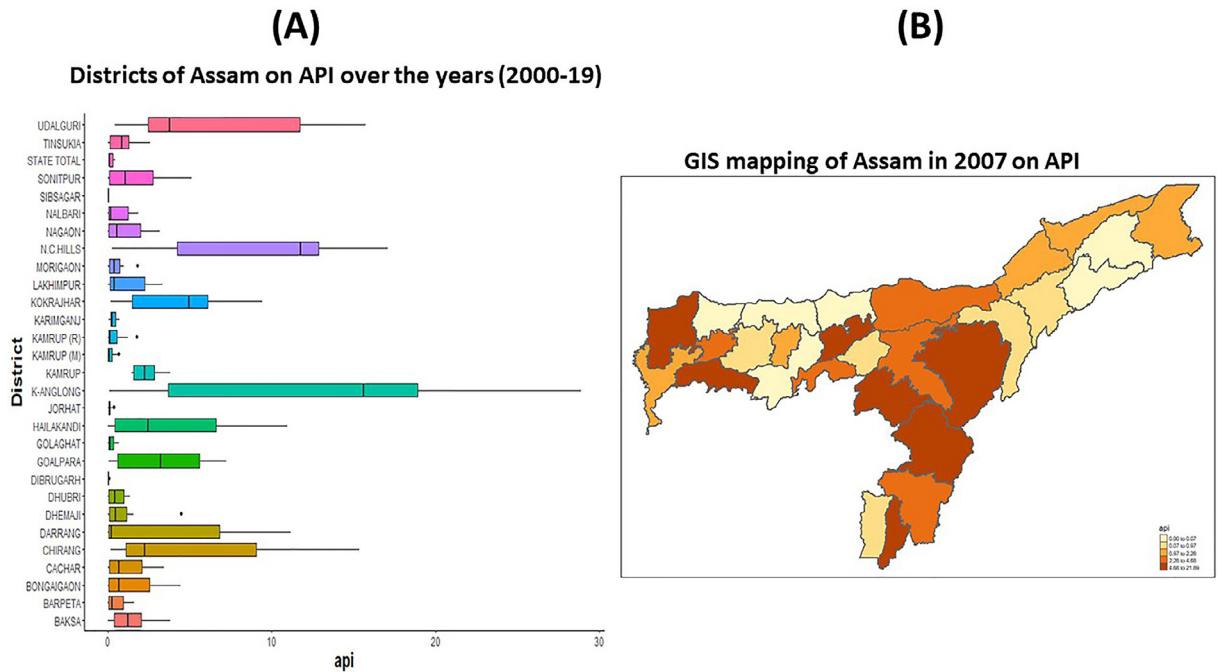


Figure 4. Graph B on tab2 gives a Box and whisker plot for all districts of a state in a particular range of years and Graph C on tab2 gives GIS map of a particular state in a chosen year based on selected malaria parameter.

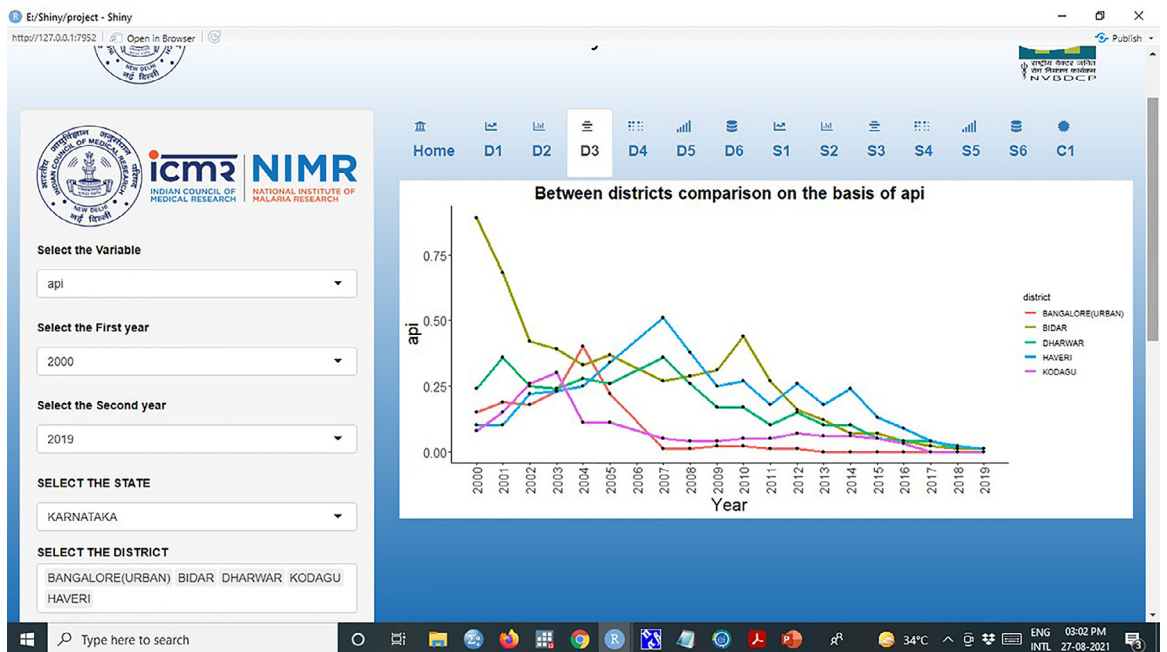


Figure 5. Graph A on tab3 gives a comparative analysis among chosen districts in a time series manner.

challenge regarding the need to control malaria via interventional tools such as radical cure (Figure 8).
Tab D6: Tab D6 presents the data in tabular form. Like tab D1, users can select a state or states followed by a district or districts and the range of years they

are interested in (by default all years are selected). Data are displayed in the form of an interactive table. Users may choose the number of entries per page and sort the data on any variable using the arrow icons besides each column title. In addition, the

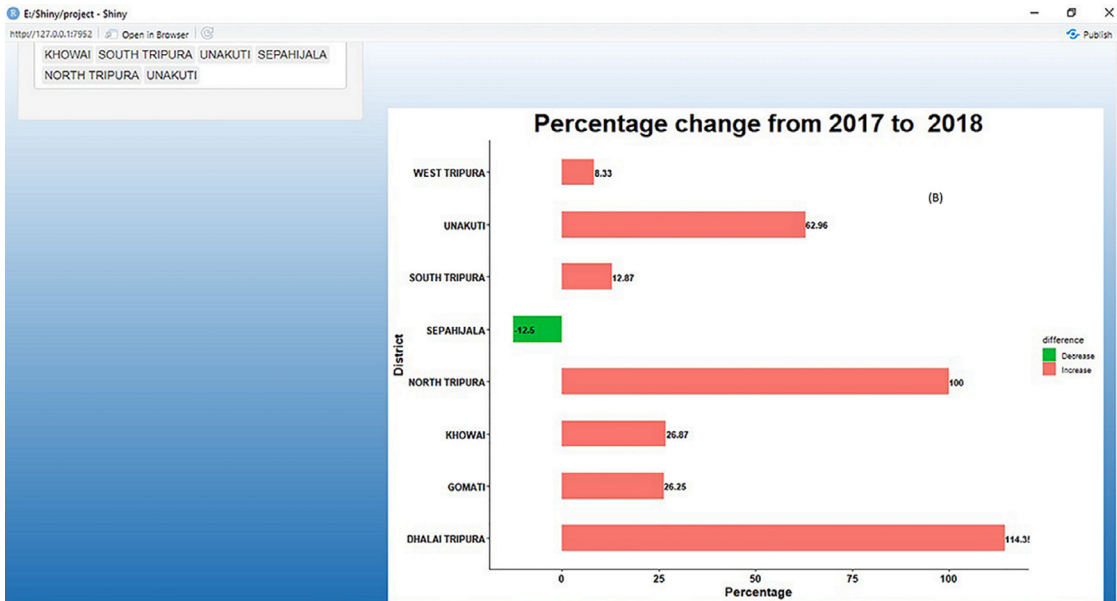


Figure 6. Graph B on tab3 gives percentage change in any particular malaria parameter in between two selected years using positive-negative bar chart.

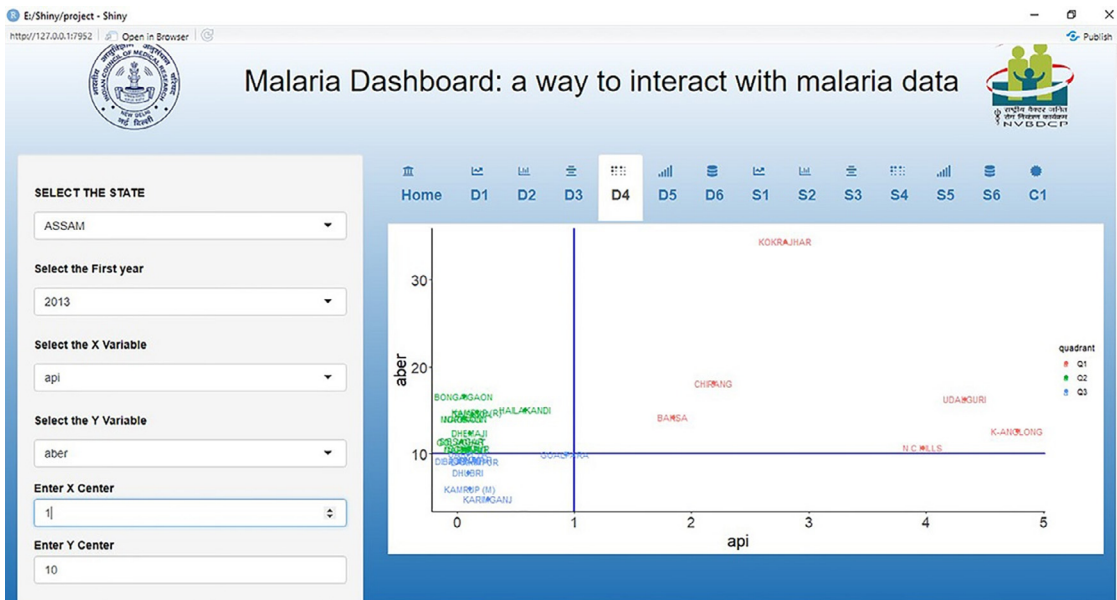


Figure 7. Tab 4 gives quadrant plot based on any two malaria parameters.

desired data may be downloaded using the download button at the bottom of the table (Figure 9).

Tab S1-S6: Similar to tabs D1 to D6, which analyze district-level data, the tabs S1 to S6 provide analysis of state-level data on the same lines.

Tab C1: Tab C1 is specifically designed to study the malaria situation at the country level. Users may analyze data of any malaria parameter for all the states or districts at once. The data are displayed in geographical

maps which can be modified based on the user input using left-hand panel inputs. Here, users may select color schemes (such as YlOrRd, YlOrBr, YlGnBn, YlGn, Reds, and RdPu etc.) and categorization methods (such as pretty, equal, quantile, Jenks, cont, hcluster, fisher, sd, bclust etc.) as per their need. For example, if one is interested in seeing the progression of API in north eastern states of India from 2010 to 2018, this can be easily done in this Tab (Figure 10).

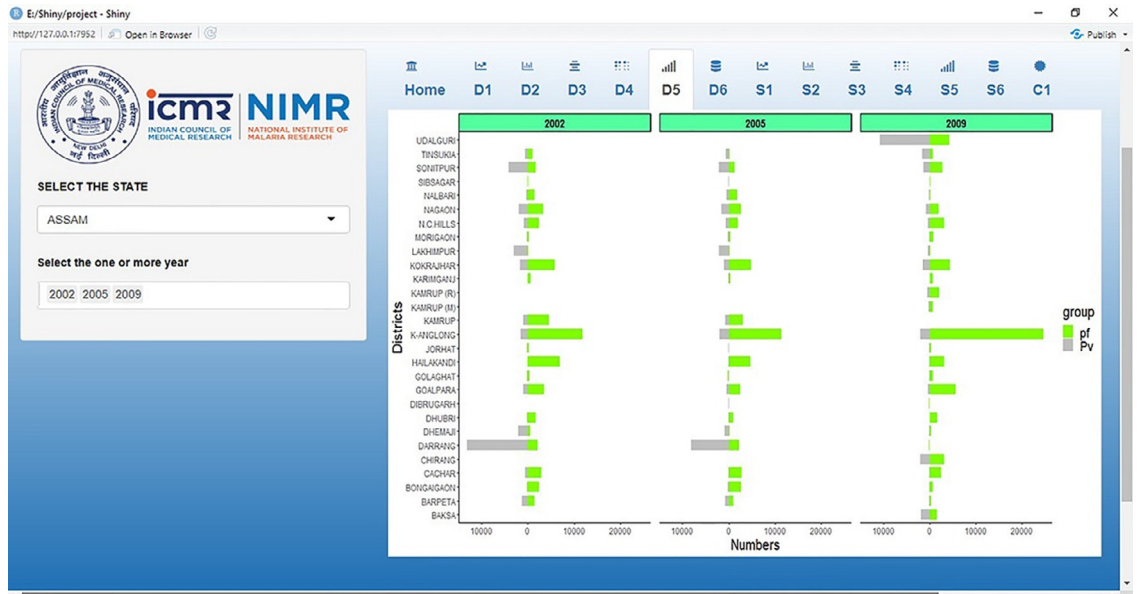


Figure 8. Tab 5 gives Pv and Pf distribution for all the districts in a selected state over different years.

	state	year	district	districtoriginal	popin000s	population	bsc	bse	pv	pf
40	ASSAM	2000	CACHAR	CACHAR	1498	1498000	101803	101803	10	3886
41	ASSAM	2000	DARRANG	DARRANG	1540	1540000	133625	133625	14266	1328
42	ASSAM	2000	DHEMAJI	DHEMAJI	583	583000	21892	21892	809	17
43	ASSAM	2000	DHUBRI	DHUBRI	1592	1592000	124435	124435	243	1829
635	ASSAM	2001	CACHAR	CACHAR	1551	1551000	93073	93073	7	3847
636	ASSAM	2001	DARRANG	DARRANG	1604	1604000	153338	153338	15708	2241
637	ASSAM	2001	DHEMAJI	DHEMAJI	583	583000	27881	27881	705	86
638	ASSAM	2001	DHUBRI	DHUBRI	1602	1602000	137859	137859	231	1971
1238	ASSAM	2002	CACHAR	CACHAR	1432	1432000	86336	86336	560	2912
1239	ASSAM	2002	DARRANG	DARRANG	1618	1618000	145994	145994	13074	2086
1240	ASSAM	2002	DHEMAJI	DHEMAJI	585	585000	37741	37741	2071	558
1241	ASSAM	2002	DHUBRI	DHUBRI	1604	1604000	137224	137224	175	1790
1852	ASSAM	2003	CACHAR	CACHAR	1157	1157000	88829	88829	15	3941

Figure 9. Tab 6 gives data in an interactive data table.

For detailed functioning and analysis of NIMR-MDB, a user manual of IMR-MDB has been enclosed as supplementary material (User Manual, supplementary material).

Discussion

A large quantity of data related to malaria are being collected every year in India at various levels like state, district, community health centers (CHCs), primary health centers (PHCs), sub-centers (SCs), and district

hospitals. Therefore, there is a need to have a unified platform like the NIMR-MDB which is tailor-made according to the Indian health structure and caters to the understanding of malaria epidemiology in India via integrating all available malaria data. Our NIMR-MDB is a fully interactive, flexible, and user-friendly program for rigorous and rapid analysis of malaria epidemiological data. Though WHO’s District Health Information System (DHIS2) is available for use, India has not subscribed to it; therefore there is no digital dashboard being used in India to the best of our knowledge. The

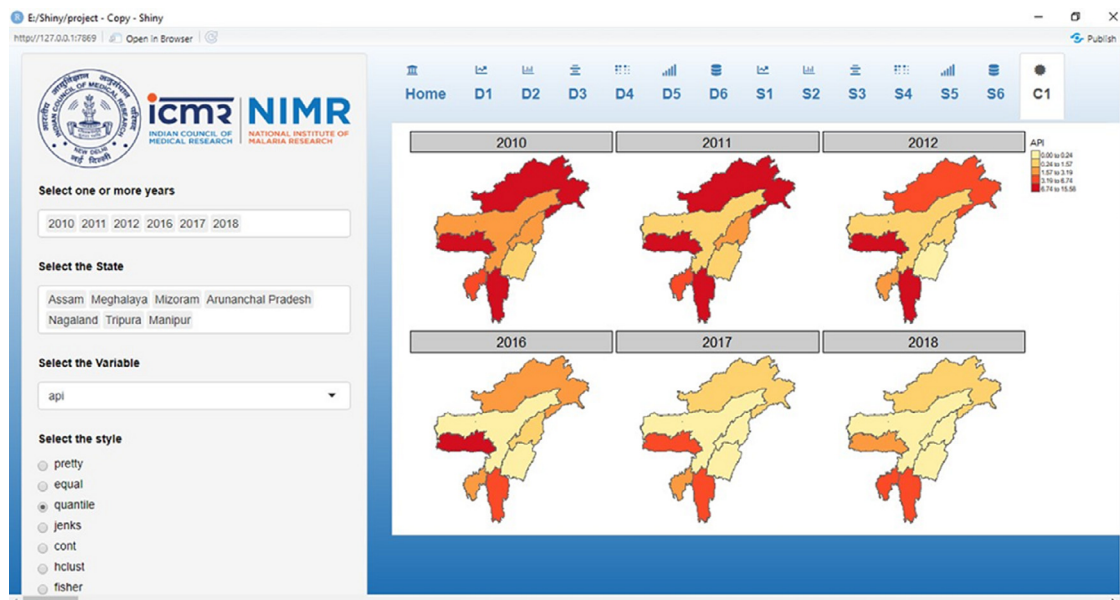


Figure 10. Tab C1 gives GIS mapping of malaria parameters at state or district \ level.

NIMR-MDB can be used locally without setting up a server or can be made available to all by hosting it on a certified online platform such as 'shinyapps.io' at affordable costs. The 'Shinyapps.io' is secure by design, and each Shiny application runs in its own protected environment where access is always SSL encrypted.³⁶ NIMR-MDB is designed with tremendous analytical capacity as it is developed in R software, meaning that the analytic tools available in R can be embedded in NIMR-MDB. For example, forecasting techniques such as time series regression, Seasonal Auto Regression Integrated Moving Average (SARIMA), random forest regression, support vector machine, gradient boosting, and ridge regression can be embedded in NIMR-MDB for the forecasting of malaria cases in future. Indeed, in the future, NIMR-MDB can also be co-opted for early warning calls.

The NIMR-MDB can become a central resource for all users on a broader scale for malaria research and control. We also plan to overlay the following data in due course of time:¹ vector distributions across India,² environmental data,³ insecticide resistance status of malaria vectors,⁴ vector bionomics data,⁵ malnutrition indices,⁶ hemoglobinopathies,⁷ drug resistance data,⁸ and real-time incidence data to make it more useful for the researchers and the policymakers. Over time, these comprehensive data sets will enhance the utility of the NIMR-MDB and allow an expanded user base. Specifically, the NIMR-MDB will help data analyses and digital monitoring for the national malaria control program. For example, analysis of any particular district in a time series manner will allow immediate assessment of the effectiveness of past malaria control interventions. Ranking districts within a state based on malaria

indicators (such as malaria cases, API, SPR, Pf %, AFI, RT) for a specific year will help assign the appropriate intervention measures in a graded and stratified manner. The NIMR-MDB will also encourage malaria data collection in a digitized format for near real-time malaria reporting via this interface. We also envisage that the NIMR-MDB can be used in the community to track malaria if they plan to migrate or travel for work or leisure. It will empower communities to understand malaria epidemiology while simultaneously allowing them to track the progress of malaria elimination.³⁷⁻³⁸ From our perspective, the NIMR-MDB represents the most significant step in disseminating malaria epidemiological data in India. We feel that its deployment in India will present a watershed moment not only for malaria control but for other infectious diseases in the elimination phase³⁹⁻⁴⁰ such as visceral leishmaniasis and lymphatic filariasis.

Contributors

AS designed the study and CPY developed NIMR-MDB. Both AS and CPY analyzed and refined the NIMR-MDB utilities. AS and CPY wrote the paper.

Data sharing statement

Data may be obtained from a third party and are not publicly available. R code is available on GitHub and can be accessed through below link (<https://github.com/nimrmdb/sdb/blob/main/app.R>).

At present MDB has not been uploaded on online due to data protection issues but a similar dashboard as a proof of concept on simulated data (or toy data) can be accessed through <https://nimrmdb.shinyapps.io/>

MDBschool/ by using below credentials for reference purpose only. (User Name: school, Password: pass1)

Guarantor

Amit Sharma, Scientist-G & Director, ICMR-National Institute of Malaria Research, New Delhi

Editor note

The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

Declaration of interests

There is no competing interest.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lansea.2022.100030.

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