Reconstruction of the great famine of western india using historical rainfall and global reanalysis datasets: challenges and uncertainties

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***Abstract*— The Deccan Plateau in Western India has a semi-arid climate. Historically, the region has experienced multiple hydrological disasters, affecting the agriculture and thereby the peasants' life. The region suffered extensive water scarcity during the Great Famines between 1876 and 1878. According to the British India's Famine Commission, the total fatality crossed the 5 million mark, however the actual numbers are supposed to be way more than that. Although there has been some statistical analysis of the event, spatial analysis including the extent and severity has not been conducted. The final goal of this research is to reconstruct the hydrological conditions of the great famine, using hydrological modelling as a tool. In this paper, we show the different challenges involved in doing so along with the uncertainty of the input data required for such analysis.**

Keywords—19th century, Drought, Historical analysis

I. INTRODUCTION (*Heading 1*)

Droughts are natural disasters that affect agriculture, flora and fauna, natural resources as well as disrupt human livelihood. Natural disasters such as floods and droughts are seen throughout the globe and are more often than one might think. They affect millions of people globally every year [1]. Although, floods last from a few days to a couple of weeks, droughts on the other hand are widespread long-term persistent phenomenon. Over a million people had died globally as a result of droughts since 1974 [2].

Droughts are quite common natural disaster in India, with one drought in every three years in some part of India [3]. In India, around 94 million hectares are drought prone regions which affects over 400 million people. Figure 1 lists the monsoon rainfall anomaly for India during 1871-2003. A total of 19 major floods and 23 major droughts occurred in some parts of India.

Recently many researchers have tried to do short-term and long-term studies on droughts in the mid to late 20th century and early 21st century [4-6]. However, no study has been conducted specifically for the great famine. The final goal of this research is to understand the great famine from the hydrological perspective. In order to achieve this goal, an attempt has been made to reconstruct the historical meteorological event (Great Famine) in the Indian sub-continent.

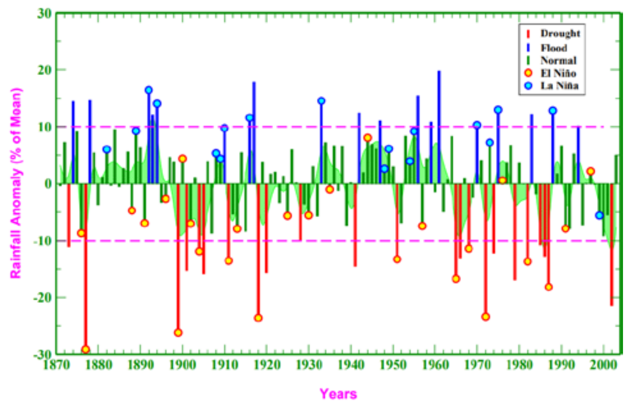


Figure 1: All-India summer monsoon rainfall, 1871-2003

(source: Rupa Kuman Kolli, IITM, Pune, India)

II. THE GREAT FAMINE

The most severe drought happened in the year 1876, the effects of which lasted until the year 1878. Figure 2 shows a historical map of the great famine, which hit large part of the Deccan plateau. Just following the great famine was a malaria epidemic (shown in light red color, fig.2). The famine commission at the all British India level, which was set up in 1878, reported the total number of deaths amounted to around

Figure 2: Extent of the Great Famine

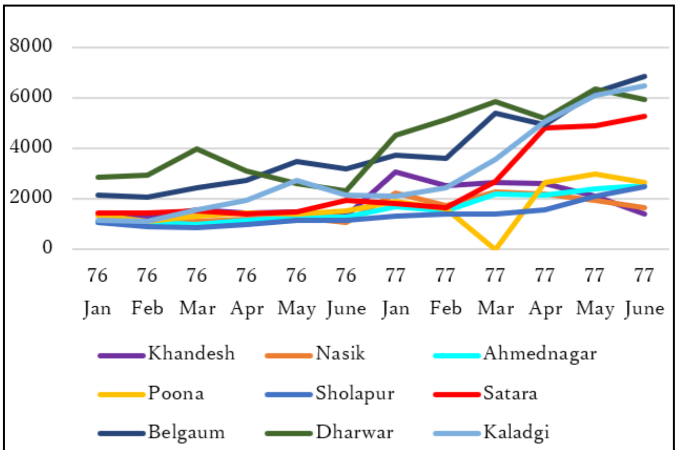


Figure 3: Death registration in the Bombay presidency

5 million. Finally, Famine Code was enacted in 1883, on which famine policies in the British India were established based.

III. MORTALITY DURING THE GREAT FAMINE IN THE BOMBAY PRESIDENCY

One of the most severely affected regions was the Bombay presidency. Figure 3 shows the district-wise mortality of the region in 1876 and 1877. The patterns of mortality became explicit in 1877. Districts of Dharwar, Belgaum, Bijapur (Kaladgi) and Satara had much higher mortality than other districts. Interestingly, Dharwar, Bijapur (Kaladgi), and Belgaum were in the Bombay Karnatak, namely the southern part of the Bombay Presidency. Satara District was located north of the Bombay Karnatak. These four districts were contiguous to one another, and Satara District was in the border between the Bombay Deccan and the Bombay Karnatak. The northern half of the district was less effected compared to the southern half. It indicates mortality rose as areas went near the southern part of the Bombay Presidency even at the sub-district level. Moreover, Khandesh, the northernmost district among the above nine districts, had the lowest mortality in June 1877. From the figure it can be clearly seen that the mortality kept on increasing as we move towards the southern direction.

IV. HYDROLOGICAL MODELLING

Since this complete extent of the great famine is huge, as a pilot study, the Bhima river; a tributary river of the Krishna river, has been selected (figure 4). The Bhima river is 861 km long, with a total catchment area of around 70,614 km^2.

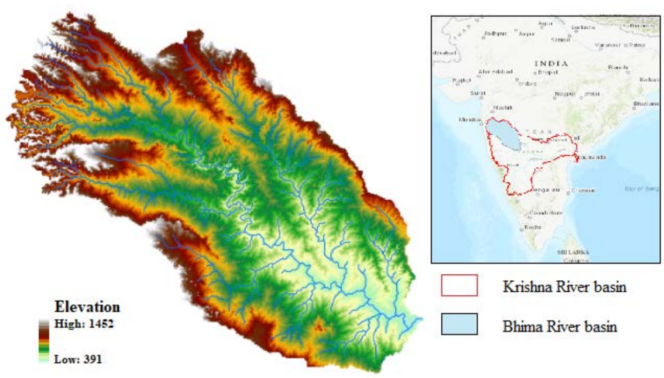


Figure 4: The study area: Bhima River basin.

In this research we used the Water and Energy Budget-based Distributed Hydrological Model (WEB-DHM) [7,8]. This model was developed by coupling a simple biosphere scheme (SiB2) with a geomorphology-based hydrological model to describe water, energy and CO_2 fluxes at a basin scale. It calculates evapotranspiration based on both water and energy balances in each model grid and therefore has a more solid physical foundation relative to the traditional hydrological models.

The overall structure of WEB-DHM is shown in figure 5. The figure 5 (a) shows the sub-basin; (b) shows the sub-division from sub-basin to flow intervals; (c) shows the discretization from a model grid to several geometrically symmetrical hillslopes; and (d) shows the detailed process descriptions of the water moisture transfer from atmosphere to river.

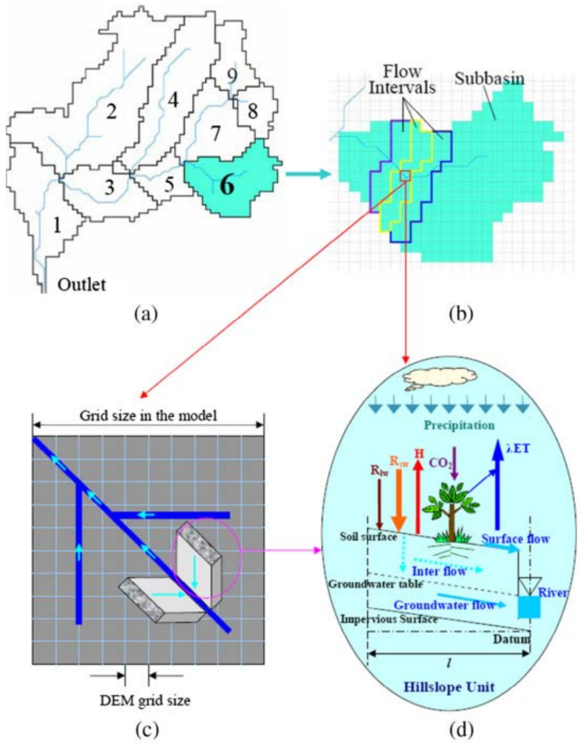


Figure 5: Overall structure of WEB-DHM model

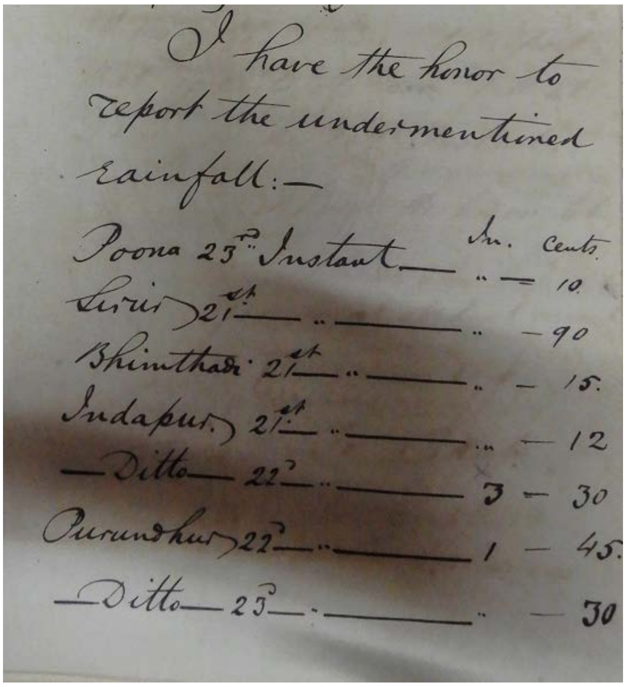
A. Input data

Like most other models WEB-DHM uses two kinds of data, (a) static physical data such as topography data (DEM), landuse data, soil data, etc. and (b) variable meteorological data such as precipitation, humidity, wind speed, air pressure, air temperature and downward solar radiation (short wave radiation, long wave radiation).

B. Data availibility

The target time period for this analysis is set as 1872-1878. The static datasets usually don't change even over many decades. Therefore, these data can be assumed to have not changed drastically. However, that is not the case for the meteorological data.

Even though the great famine happened during 1874-1876 (and effects lasted until 1878), daily recorded precipitation data is available from 1878 onwards. These daily data were obtained from the British library at the London School of Economics and Political Science (in form of pdf files). There are however some hand-written data for the years prior to 1878. Figure 6 shows one such example. If you look closely, the precipitation values of some days are mentioned. Upon further investigation of hundreds of such pages, it was found that there are many missing days. The data thus is incomplete. This makes the data unusable at its current status for any modelling purposes.


I have the honor to
report the undermentioned
rainfall:—

		In.	Cents
Poona	23rd Instant	..	10
Sirur	21st	..	90
Bhimthadi	21st	..	15
Indapur	21st	..	12
Ditto	22nd	3	30
Purundhur	22nd	1	45
Ditto	23rd	..	30

Figure 6: Old hand-written precipitation data

But apart from the precipitation data, no other meteorological data is available. Although there are no observed data, some GCM outputs and reanalysis dataset are available during 1870s on a global scale. One such dataset is the 20th century Reanalysis datasets provided by the National Oceanic and Atmospheric Administration (NOAA) (https://www.esrl.noaa.gov/psd/data/ 20thC_Rean/). It contains all the meteorological needed to setup the WEB-DHM model.

C. Data uncertainity

As introduced in the previous section, the NOAA 20th century Reanalysis can be a viable option to be used as the input data for the model. Figure 67shows the mean monthly average temperatures (1871-1890) for June and July months and the corresponding values for 1876 and the differences.

As seen from those figures, there is not much change in temperature in the Deccan plateau of the Indian sub-continent. Very interestingly the major differences can be seen in the north India, near the Himalayas.

Figure 8 shows similar figures for relative humidity values. In this case however, a large difference in relative humidity can be seen in the deccan plateau along with a higher difference in the North India along the Himalayas.

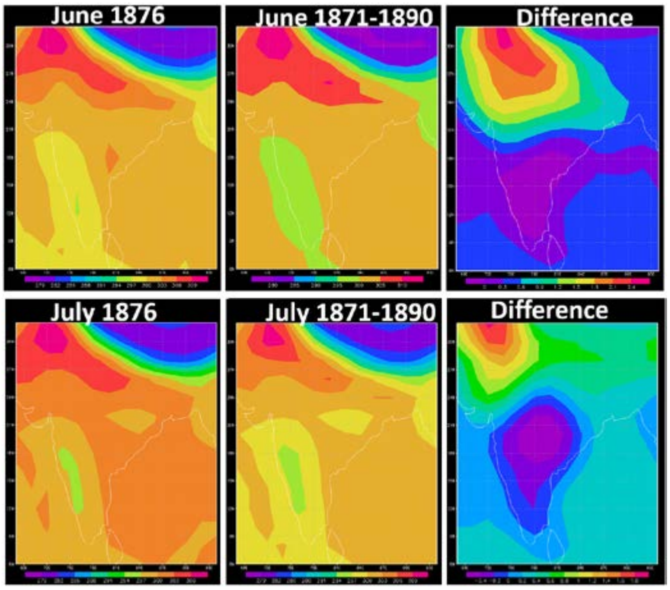


Figure 7: Comparison of temperature during June and July 1876 with mean values for 1871-1890

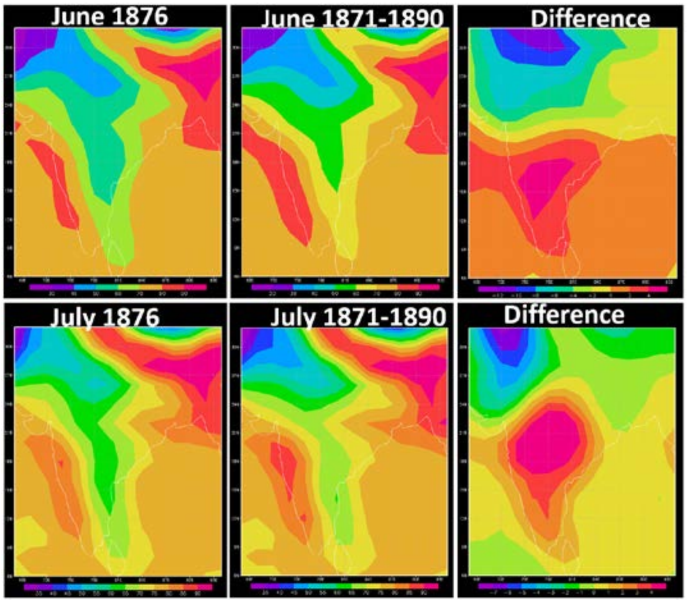


Figure 8: Comparison of relative humidity during June and July 1876 with mean values for 1871-1890

D. Initial model setup

In order to develop a hydrological model, available discharge data at some points along the river channel is needed for initial set-up, calibration and validation. Since the available data is limited for the 19th century, with no observed/measured river discharge data, it is almost impossible to set-up and calibrate the model at that time. The model has to be setup for such a period where these conditions are met. Since, the study area also experienced a drought period during 1998-2004 and all the required data are available, an initial model has been setup for the period. Figure 9 shows the hydrographs are two locations along the Bhima river.

The model has been calibrated for 1997 and validated for the years 1998-1999, with NSE values of 0.87 & 0.89 and R^2 values of 0.82 & 0.85 respectively. These values mean that the model is applicable for the study area.

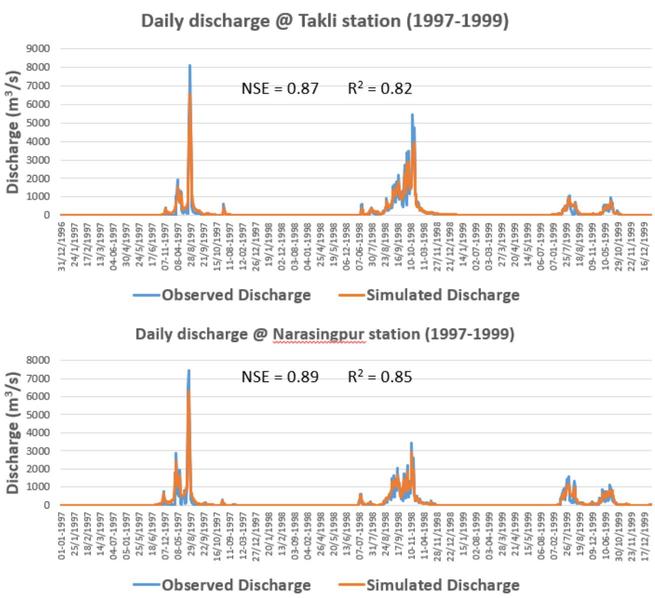


Figure 9: Initial model setup; calibration year – 1997; validation years – 1988-1999

V. DISCCUSIONS

From the figures 7 and 8, although we can see some difference in temperature and relative humidity in the target region during the great famine period, the difference is rather small. The main reason is due the inability of the reanalysis dataset to capture the drought/famine period. Based on this analysis, it seems that the NOAA 20th century reanalysis data is not well suited to be used as the input data for setting up the WEB-DHM model to analyze the great famine in 1876.

There however, are many other Global Circulation Models (GCM) which have historical dataset, especially the CMIP5 experiments. It has global GCM outputs since 1850s. There are many sub-experiments which consider different climatic and physical conditions. Choosing an appropriate GCM output would be the next step of this research.

The observed hand-written precipitation data is also found to be incomplete. Some method must be developed either interpolation or duplication to fill-up the missing values, to be able to use the data as an input for hydrological models.

The initial hydrological model for the study area has been developed. Next step of the research is to use this same model and run it for the time period of 1875-1879. As mentioned earlier, a better alternative for meteorological data is also required.

REFERENCES

[1] D. Wilhite Drought: A Global Assessment, Natural Hazards and Disasters Series, Routledge Publishers, UK (2000), pp. 213-230

[2] United nations (UN): Trends in Sustainable Development 2008–2009. United Nations publication, United Nations Division for Sustainable Development (2008)

[3] Goyal, M.K., Gupta, V., Eslamian, S., 2017. Hydrological Drought: Water Surface and Duration Curve Indices. Handbook of Drought and Water Scarcity: Principles of Drought and Water Scarcity.

[4] Singh, V., Yadav, R. R., Gupta, A. K., Kotlia, B. S., Singh, J., Yadava, A. K., Singh, A. K., and Misra, K. G., 2017. Tree ring drought records from Kishtwar, Jammu and Kashmir, northwest Himalaya, India. Quaternary International, 444(A), 53-64.

[5] Kumar, K. N., Rajeevan, M., Pai, D. S., Srivastava, A. K., and Preethi, B. 2013. On the observed variability of monsoon droughts over India. Weather and Climate Extremes, 1, 42-50.

[6] Dhorde, A. G., and Patel, N. R. 2016. Spatio-temporal variation in terminal drought over western India using dryness index derived from long-term MODIS data. 2016, 32, 28-38.

[7] Wang, L., Koike, T., Yang, D.W. and Yang, K., 2009a. Improving the hydrology of the simple biosphere model 2 and its evaluation within the framework of a distributed hydrological model. Hydrol. Sci. J.-J. Des Sci. Hydrol., 54 (6), 989– 1006.

[8] Wang, L., Koike, T., Yang, K., Jackson, T.J., Bindlish, R. and Yang, D., 2009b. Development of a distributed biosphere hydrological model and its evaluation with the southern great plains experiments (SGP97 and SGP99). J. Geophys. Res., 114 (D8).