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Global and countrywide prevalence of subclinical and clinical mastitis in dairy cattle and buffaloes by systematic review and meta-analysis

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A R T I C L E I N F O

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A B S T R A C T

In the present study, subclinical mastitis (SCM) and clinical mastitis (CM) prevalence for various countries in the World were calculated by using online and offline databases. The SCM and CM prevalence studies reported during 1967-2019 were collected, reviewed, and a meta-analysis was done in R-Software. A total of 222 and 150 studies from the World and 103 and 37 studies from India on SCM and CM, respectively were included. The pooled prevalence of SCM and CM were 42% [Confidence Interval (CI) 38-45%, Prediction Interval (PI) 10-83%] and 15% [CI 12-19%, PI 1-81%] in the World respectively, 45% [CI 40-49%, PI 11-84%] and 18% [CI 14-23%, PI 3-60%] in India respectively. Continent-wise analysis indicated a higher prevalence of SCM in North America and CM in Europe and among the countries, a higher SCM prevalence in Uganda and CM in the United Kingdom was observed. Further, species-wise indicated a higher SCM and CM prevalence in buffaloes of the World than the cattle. Based on method-wise, SCM and CM prevalence were high in somatic cell count and clinical examination, respectively in the World. The SCM prevalence was higher than CM and indicated the importance of SCM in dairy cattle. This might result in low milk productivity in dairying and may set off losses to dairy farmers. Hence, there is an urgent need to reduce the SCM and CM prevalence by implementing scientific dairy management, good feeding practices, and timely therapeutic interventions for increasing the benefits from dairying to the farmers in the World.

1. Introduction

Mastitis causes economic losses to the dairy farmers in the World and in India, which mainly affects milk production. This production disease is considered an important disease of dairy cows which results in a reduction of milk production, loss in milk quality and quantity, losses due to discarded milk, premature culling, treatment costs, and extra labour cost (Hogeveen et al., 2011). Mastitis is a worldwide production disease of dairy cows (FAO, 2014). Mastitis can be classified into three types, namely sub-clinical, clinical and chronic mastitis, and it depends on causative organisms, breed, age, immunity, and stage of lactation of the animal. Sub-clinical mastitis (SCM) causes major loss to milk production due to the absence of any visible changes in milk and difficulty in detection. Clinical mastitis (CM), characterized by swelling of the udder, milk containing flakes, clots, and watery milk are observed grossly. Chronic mastitis is a rare form but leads to persistent inflammation of the mammary gland in dairy animals. The estimated annual economic losses due to mastitis were reported to be US$ 200 per cow per year (Costello, 2004). Viguier et al. (2009) reported an estimated total loss of US$ 2 billion by the year 2009 in the United States of America (USA) was accounted for due to mastitis. The estimated annual economic loss due to both subclinical and clinical mastitis in India was US$ 98,228 million [7165.51 crore Indian Rupees] as reported earlier (Bansal and Gupta, 2009).

The meta-analysis, an innovative tool for estimating the prevalence of various livestock diseases from different countries, and many studies have been reported in the field of Veterinary Science in recent times (Krishnamoorthy et al., 2020). Haidich (2010) indicated that meta-analysis is one of the formal, quantitative, epidemiological study design, which was used to systematically evaluate the previously reported studies to develop meaningful assumptions in the same area of research. The main objective of conducting a meta-analysis is to

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summarize and integrate results from several previous studies, analyze the differences reported in the prevalence in different studies, to overpower the small sample sizes used in the individual studies. It also helps in analysing the endpoints which require larger sample sizes, increasing the precision in effect estimates, to determine whether the new studies are needed for further and to generate new hypotheses for the studies in the future (Krishnamoorthy et al., 2019a, 2019b). The precarious steps to be considered in a meta-analysis study are the selection of studies, heterogeneity of prevalence reported, availability of evidence, and method of data analysis employed (Walker et al., 2008). There are few studies conducted in the past, by using meta-analysis method for estimating the prevalence of subclinical and clinical mastitis, major mastitis pathogens in India (Krishnamoorthy et al., 2017), anaplasmosis in dairy animals in India and the World (Krishnamoorthy et al., 2019a), and livestock-associated methicillin-resistant *Staphylococcus aureus* in animals in India (Krishnamoorthy et al., 2019b).

The cattle and buffalo population in the World were 1,489 and 206 million, respectively as available online (FAOSTAT, 2020). The annual combined cattle and buffalo milk production was 187.75 million tonnes during the year 2019 in India, which has increased by 6.5% when compared to 2018, and 394 grams per day was the per capita availability of milk as reported (BAHS, 2019). India also ranks first in the buffalo population and second in cattle population after Brazil (193.5 million) in the World (FAOSTAT, 2020). In India, the cattle and buffalo population were 192.5 and 109.8 million out of the total livestock population of 535.8 million, as per the 20th Livestock census (BAHS, 2019). Since the cattle and buffalo population was more in number in India, it was planned to calculate the prevalence estimates of subclinical and clinical mastitis separately and to study in detail as an example to other countries in the World. There are numerous studies on SCM and CM prevalence, reported from various geographical locations in the World. However, the prevalence reported is variable from study to study due to several factors including the period of study, location of the study, animal breed, lactation stage, sample numbers tested, sampling methodology employed and dairy managemental practices followed. Two studies, separately on SCM and CM prevalence in dairy cows in India for the period 1995-2014 by using meta-analysis were reported (Bangar et al., 2015, 2016). Another study from India reported the prevalence estimates for SCM and CM along with subgroup analysis by using studies reported during 1995-2015 based on a meta-analysis (Krishnamoorthy et al., 2017). However, there were no studies on SCM and CM prevalence estimates for a particular country or continents in the World as a whole, based on a meta-analysis, other than India. It is pertinent to collect the information on the prevalence of SCM and CM across different countries in the World, which will act as baseline information for planning mastitis prevention and control strategies in different countries of the World and India. Further, the studies on SCM and CM prevalence will be available in one place, which enables easy retrieval of mastitis studies in near future, by many researchers. Keeping this in mind, the present study was undertaken to do a meta-analysis of available literature on the prevalence of subclinical and clinical mastitis in the World to obtain the mastitis prevalence estimates among dairy cows from the studies reported during the period 1967-2019.

2. Materials and methods

2.1. Search strategy

A systematic literature search was performed by using keywords such as “mastitis prevalence, mastitis AND prevalence, subclinical mastitis, subclinical mastitis AND prevalence, clinical mastitis, clinical mastitis AND prevalence, bovine mastitis, bovine mastitis AND prevalence, prevalence” and followed as per the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2015) for identifying the studies on the prevalence of subclinical and clinical mastitis in dairy cows in the World. The databases PubMed, Elsevier, Springer, Indian journals.com, Consortium of e-Resources in Agriculture (CeRA) under the Indian Council of Agricultural Research, and Google Scholar were searched for the publications on SCM and CM prevalence. More than 421 and 215 articles from the World and India were searched and identified from the database search. The studies from different journal publications were from 1967 to 2019 and 1995 to 2019 for the World and India, respectively on SCM and CM prevalence. The studies selected based on the characteristics of the publications which clearly state the following details including author names, year, country, state, number of samples tested, number of positive samples, diagnostic methods employed, and species either cattle/buffalo. Finally, the original articles were reviewed in detail and the references cited from the retrieved articles were searched again for some more relevant studies. The retrieval dates for the studies were limited to the period from January 1967 to December 2019 and the retrieval language was limited to English only.

2.2. Data processing and filtration

The SCM and CM prevalence studies were reviewed in full and included for meta-analysis based on the set inclusion criteria such as cross-sectional and observational studies (prevalence studies) and published in peer-reviewed journals either online or offline. The exclusion criteria for the studies included were case reports, review articles, and consideration of sample size. The study details were extracted from the characteristics reported in each study onto Microsoft Excel data sheets with a designed format. These characteristics include the year of publication, author names, study eligibility criteria, study period, species of animals tested, numbers of samples positive for SCM or CM, the total number of samples tested, prevalence of SCM, and CM, the diagnostic approaches utilized. The methods engaged were California mastitis test (CMT), surf field mastitis test (SFMT), white side test (WST), somatic cell count (SCC) in various studies for SCM, and bacterial culture examination and clinical examination (CE) for CM. The pooled prevalence estimates for SCM and CM were calculated by considering the highest value of prevalence obtained by different methods employed. There are three steps in data filtering, the first step is to ensure that the selected studies are coherent with the purpose of the meta-analysis. The second consisted of a critical and detailed review of each study selected for meta-analysis and authentication of data entries. In the third step, to ensure that a selected publication should not be an outlier concerning the characteristics and studies under consideration for meta-analysis. The above steps mentioned were similar to the PRISMA guidelines as mentioned earlier.

2.3. Meta-analysis methods

In usual terms, a meta-analysis uses specialized techniques for data collection and analysis developed exclusively for new research synthesis (Koricheva et al., 2013). The whole effect may be computed from a group of combined and representative studies or criteria that provides an impartial estimate of the effect, with an increase in the accuracy of this estimate obtained by employing meta-analysis. It provides the total effect estimate from a meta-analysis, normally at the bottom, and often using a diamond to distinguish it from the individual studies (Higgins et al., 2013). The R Open source scripting software version 3.2.5 (Comprehensive R Archive Network) was employed for meta-analysis by using the R package "Meta" (Schwarzer, 2007). The meta-analysis results obtained were represented graphically by forest plots. The forest plots, otherwise known as confidence interval plots, display prevalence estimates and their confidence intervals for each study. The generalized linear mixed model and transformation for proportion used was Logit transformation, i.e., “sm=PLOGIT" for analysis purposes. The prevalence estimate was represented as square and the horizontal line extending on either side of the square indicates the 95% confidence interval (CI). The prediction interval (PI) at a 95% level was given below

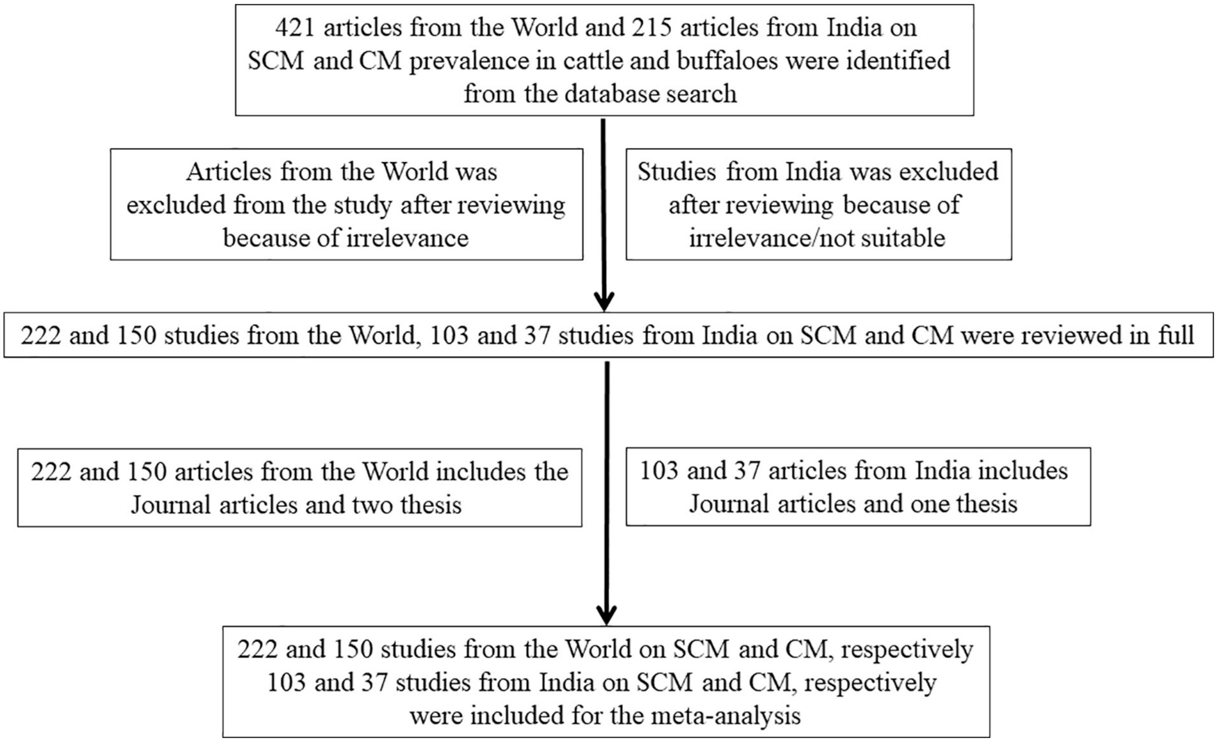

Fig. 1. Diagram showing the Subclinical mastitis (SCM) and Clinical mastitis (CM) prevalence studies from the World and India.

the forest plot as a shaded thick line. The heterogeneity between the studies included for the meta-analysis was determined by the I-Square value, Tau square value, and P values obtained in the forest plot. To reduce the heterogeneity between the selected studies on SCM and CM prevalence in the World and India, the subgroup analysis was done, based on various parameters as described earlier (Krishnamoorthy et al., 2019a) with some modifications. The funnel plot was also obtained for the meta-analysis, which was used to determine the outliers in the SCM and CM prevalence studies. The Cochran Q statistics were calculated as per the method reported earlier (Krishnamoorthy et al., 2017, 2019a, 2019b) and indicated the level of significance. If the P-value obtained was significant, the random effect model values in the forest plot were used for determining the prevalence estimates and CI. The forest plots were prepared for the overall SCM and CM prevalence estimates, continent-wise, period-wise, species-wise, method-wise, country-wise for the World. India was divided into different states and union territories based on the geographically and politically organized under one administrative Government, and further the states were grouped into five zones namely North, East, West, South, and Central zones. The overall SCM and CM prevalence estimates, period-wise, zone-wise, species-wise, method-wise, and state-wise were obtained for India. The prevalence estimates for SCM and CM were expressed as percentages and along with CI and PI at the 95 % level.

3. Results

3.1. Details of SCM and CM prevalence studies

In the current study, the systematic review and meta-analysis of SCM and CM prevalence studies in cattle and buffaloes from the World and India were carried out. The filled Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2009 checklist for the present study are given in Supplementary Table 1. The diagram revealing the details of the number of SCM and CM prevalence studies retrieved, reviewed in full, and considered for a meta-analysis are given in Fig. 1. The details of the studies including continents of the World, countries, author, year, and either SCM or CM prevalence reported are given in Table 1. The number of studies on SCM and CM prevalence from the World included for meta-analysis were 222 and 150, respectively, and have been reported from all the continents except Antarctica. The number of countries included for determining SCM and CM prevalence estimates was 50 and 44, respectively with overall 61 countries reported mastitis prevalence studies. The number of studies reported was more in cattle for both SCM [206] and CM [143] when compared to buffaloes. Method-wise comparison indicated more number of studies used the California mastitis test (CMT) for SCM and clinical examination (CE) for CM diagnosis when compared with other methods. The year-wise and country-wise number of studies reported from the World are given in Fig. 2. The SCM and CM prevalence studies reported during the period 1967-2019 and 1982-2019, respectively from the World were included for meta-analysis. More number of studies reported in the World for SCM [34] and CM [16] was during the year 2013. Ethiopia reported the highest number of studies on SCM and CM prevalence and was 63 and 55, respectively followed by Bangladesh [22] and Pakistan [17] for SCM and Egypt [10] and the United State of America [10] for CM. The SCM and CM studies from India were analyzed separately as mentioned earlier for better comparison with other countries and not included for analysis under Asia [69 SCM and 25 CM studies]. The particulars of the studies included from the different states, zones, and either SCM or CM prevalence reported from India are given in Table 2. The total number of studies used for meta-analysis was 103 and 37 on SCM and CM prevalence, respectively in India. The SCM and CM prevalence studies in India were obtained from 21 states along with one union territory and 15 states, respectively were explored. In cattle, the number of studies on SCM [81] and CM [32] was high when paralleled with buffaloes. Most of the studies employed CMT for SCM and CE for CM diagnosis in India. The details of the year-wise and state-wise number of studies included from India are shown in Fig. 3. More number of studies on SCM [14] and

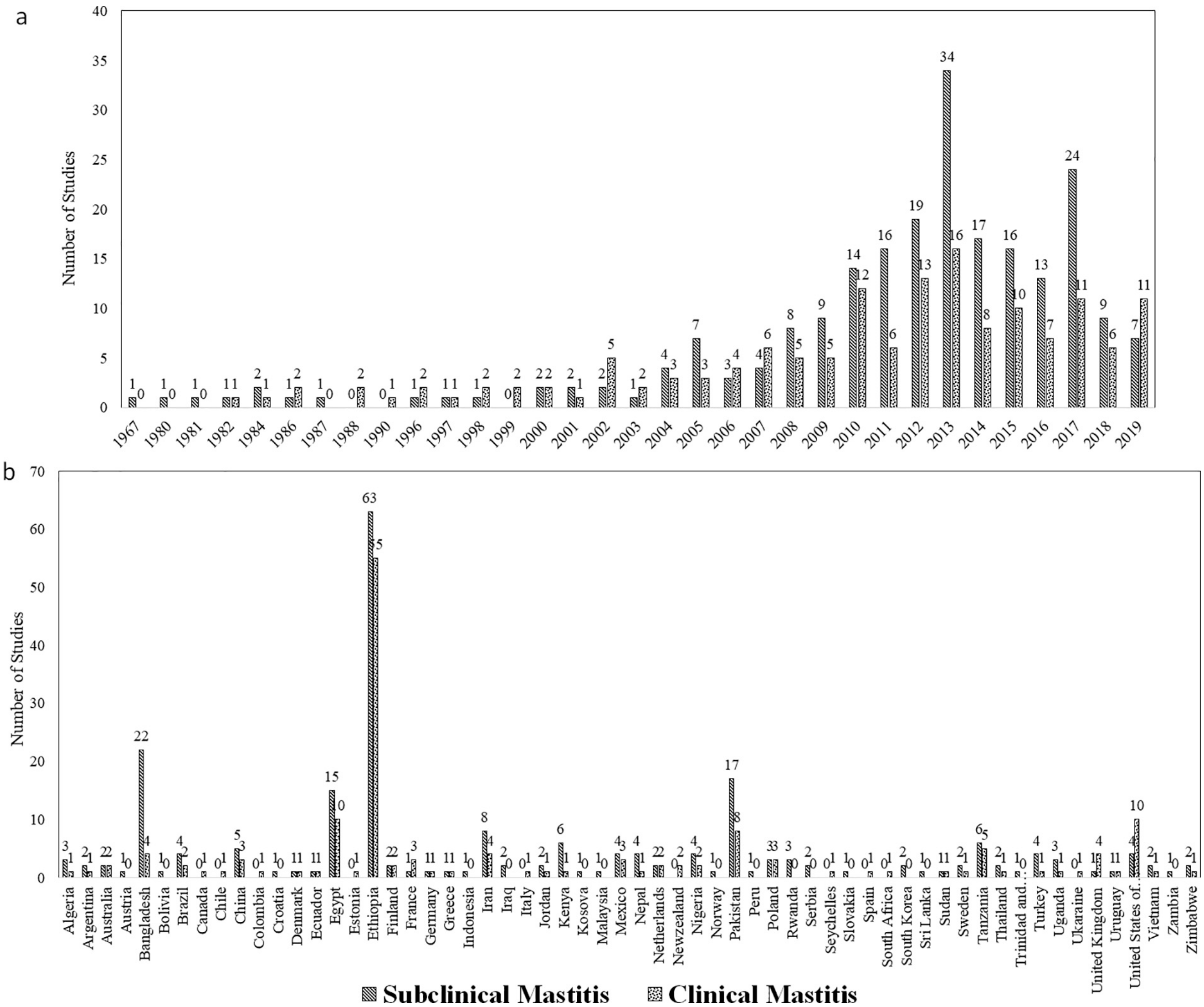

Fig. 2. Year-wise (a) and Country-wise (b) number of studies from the World on Subclinical and Clinical mastitis prevalence included for meta-analysis.

CM [5] were reported during the years 2013 and 2013 & 2017, respectively. To understand the heterogeneity between the various studies, the forest plot was employed for better visualization of meta-analysis results. Further, the subgroup analysis under different categories, the SCM and CM prevalence studies were segregated to obtain the prevalence estimates for superior understanding for both in the World and India.

3.2. Global SCM and CM prevalence

The details of the SCM prevalence estimates obtained by a meta-analysis from the World and the tests for heterogeneity are presented in Table 3. The pooled prevalence estimates for SCM were 42% [95% CI 38-45, PI 10-83%] with an aggregate of 2,51,372 samples tested from six continents of the World. The number of SCM prevalence studies incorporated was 13, 54, and 155 reported during the period 1967-2000, 2000-2010, and 2011-2019, respectively. The highest SCM prevalence [43%] was reported during the period 2011-2019 than other periods and endorses the increased prevalence in recent years. The continent-wise SCM prevalence estimates are depicted in Fig. 4. Based on continent-wise analysis indicated high SCM prevalence in North America [46%] followed by Africa [44%], Asia [42%], Europe [37%], Oceania [36%], and Latin America [34%]. Period-wise analysis i.e., up to 2000 and after 2000 of the six continents revealed increasing SCM prevalence in recent years except for Africa and Latin America, which exhibited a decreasing trend. The species-wise evaluation indicated the highest SCM prevalence in buffaloes [46%] in comparison to cattle [42%]. The SCM prevalence was highest in SCC [46%] when compared to other methods namely CMT [43%], SFMT [41%], and WST [37%]. The meta-analysis results of CM prevalence estimates obtained for the World are given in Table 4. The CM pooled prevalence estimate was 15% [95% CI 12-19, PI 1-81] with a total of 1,10,066 samples from dairy cattle and buffaloes in the World. The year-wise prevalence estimates revealed a decreasing trend over the years and lowest during 2011-19 [12%] in recent times. High CM prevalence was reported from Europe [29%] followed by other continents in the World and the lowest in Oceania [5%] was observed. Based on the period-wise analysis indicated the decreasing trend in recent years except in Africa which indicated increasing CM prevalence. The buffaloes [28%] showed a high CM prevalence than cattle [14%], based on the studies analysed from the

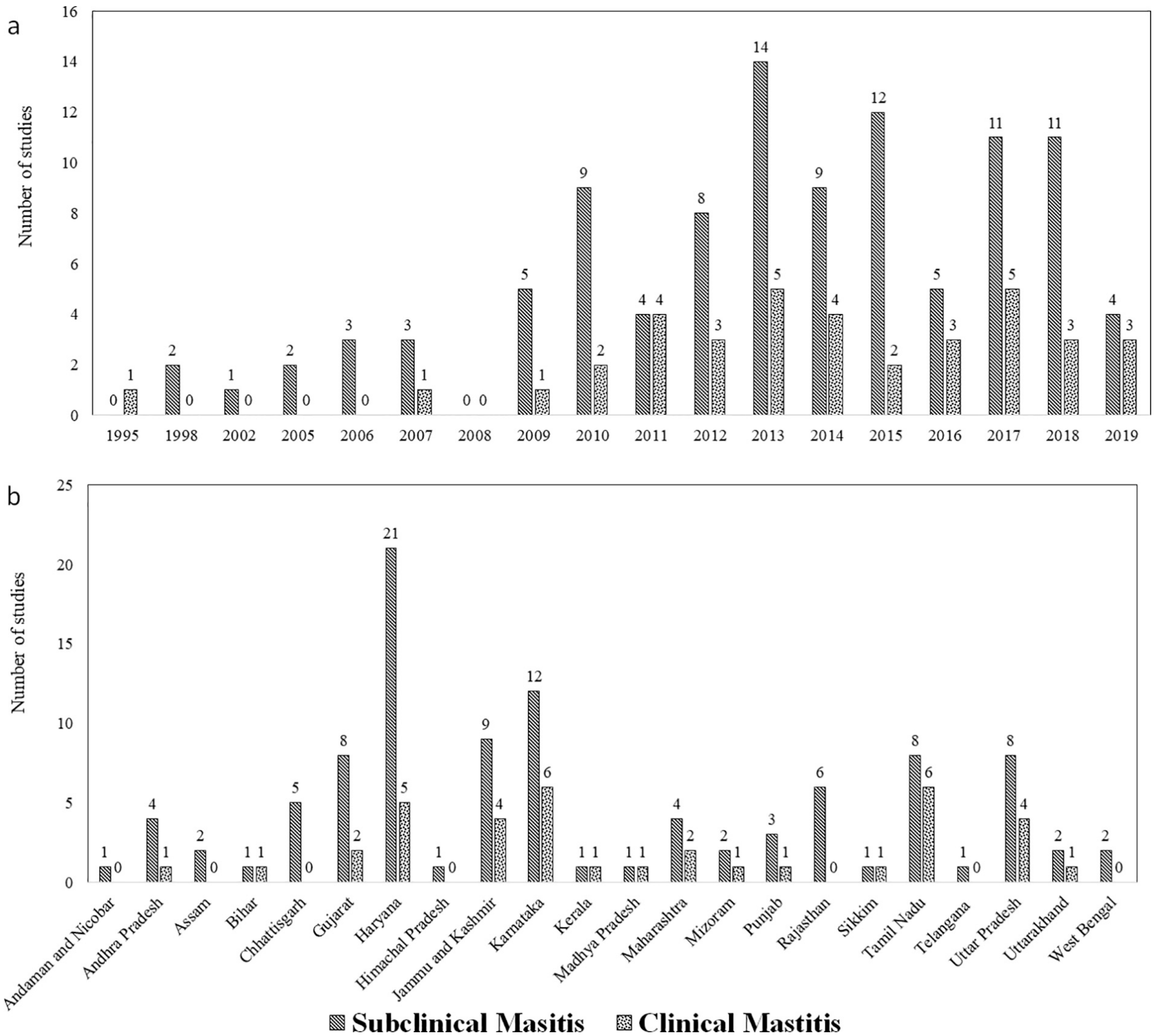

Fig. 3. Year-wise (a) and State-wise (b) number of studies from India on Subclinical and Clinical mastitis prevalence included for meta-analysis.

World. Among the studies reported, the most common diagnostic method used was CE of the udder and milk samples for CM, with a prevalence estimate of 15% [95% CI 12-19, PI 1-80%]. The Cochran Q values revealed a highly significant ($P<0.01$) difference between the studies included for SCM and CM prevalence in the World sub-grouped based on year-wise, continent-wise, period-wise, species-wise, and method-wise showing the heterogeneity between the studies selected for meta-analysis.

3.3. Countrywide SCM and CM prevalence

The details of SCM and CM prevalence values for various countries of the World attained by meta-analysis are presented in Tables 5 and 6, respectively. The number of countries included for meta-analysis was 50 and 44 for SCM and CM prevalence, respectively. The SCM prevalence was highest in Uganda [85%] followed by Indonesia [82%], Malaysia [82%], and other countries, the low prevalence was observed in Uruguay [1%]. More number of the studies encompassed from Ethiopia for both SCM and CM, when compared to other countries. The highest CM prevalence was in the United Kingdom [74%], followed by Finland [45%], the USA [35%], and other forty-one countries. The lowest CM prevalence was observed in Thailand [1%] and Ukraine [1%]. The countrywide SCM prevalence studies showed a highly significant ($P<0.01$) difference for the various countries except for Argentina, which showed a significant ($P<0.05$) difference and no significant difference was observed for Finland, Netherlands, South Korea, Thailand, and Uganda. The Cochran Q values of CM prevalence studies from various countries revealed a highly significant ($P<0.01$) difference excluding Finland and Nigeria, which showed no significant difference between the studies included for a meta-analysis.

3.4. SCM and CM prevalence in India

The particulars of SCM and CM prevalence estimates in India based

Table 1
Details of Subclinical mastitis (SCM) and Clinical mastitis (CM) studies from the World included for meta-analysis.

No.	Continents	Countries	Studies [Author and Year]	SCM-1, CM-2
	Africa	Algeria	Afri et al., 2017	1
			Akkou et al., 2018	1, 2
			Saidi et al., 2013	1
		Egypt	Abdel-Rady and Sayed, 2009	1
			Abd-Elrahman, 2013	1, 2
			Ahmed et al., 2018	1
			Amin et al., 2011	1, 2
			El-Ashker et al., 2015	1, 2
			El-Jakee et al., 2013	1, 2
			Elbably et al., 2013	1, 2
			Elhaig and Selim, 2014	1
			Elsayed et al., 2015	1, 2
			Hamed and Ziatoun, 2014	1
			Kotb et al., 2014	1, 2
			Lamey et al., 2013	1, 2
			Osman et al., 2010	1, 2
			Sayed et al., 2014	1, 2
			Zaki et al., 2010	1
		Ethiopia	Abebe et al., 2016	1, 2
			Abera et al., 2012a	1, 2
			Abera et al., 2012b	1, 2
			Abera et al., 2013	1, 2
			Abraham and Zeleke, 2017	2
			Abunna et al., 2013	1, 2
			Adane et al., 2012	1, 2
			Alemu et al., 2013	1, 2
			Almaw et al., 2008	1
			Almaw et al., 2009	1
			Amin et al., 2017	1, 2
			Ayano et al., 2013	1
			Bedacha and Menghistu, 2011	1, 2
			Belayneh et al., 2013	1, 2
			Beyene and Tolosa, 2017	1, 2
			Biffa et al., 2005	1, 2
			Birhanu et al., 2017	1
			Bitew et al., 2010	1, 2
			Dego and Tareke, 2003	1, 2
			Delelesse, 2010	1, 2
			Demissie et al., 2018	1, 2
			Duguma et al., 2014	1, 2
			Elemo et al., 2017	1, 2
			Getahun et al., 2008	1, 2
			Girma et al., 2012	1
			Haftu et al., 2012	1, 2
			Hailemeskel et al., 2014	1, 2
			Kebebew and Jorga, 2016	1, 2
			Kedir et al., 2016	1, 2
			Lakew et al., 2009	1, 2
			Lakew et al., 2019	1, 2
			Madalcho, 2019	1, 2
			Marama et al., 2016	1, 2
			Megersa et al., 2012	1, 2
			Mekibib et al., 2010	1, 2
			Mekonnen and Tesfaye, 2010	1, 2
			Mekonnen et al., 2017	1
			Michael et al., 2013	1, 2
			Moges et al., 2012	1, 2
			Mulate et al., 2017	1
			Mulshet et al., 2017	1
			Pal et al., 2017	1
			Regassa et al., 2013	1, 2
			Sarba and Tola, 2017	1, 2
			Seid et al., 2015	1, 2
			Shiferaw and Telila, 2016	1, 2
			Sori et al., 2005	1, 2
			Tadesse and Chanie, 2012	1, 2
			Tafa et al., 2015	1, 2
			Tekle and Berihe, 2015	1, 2
			Tesfaye and Abera, 2018	1
			Tesfaye et al., 2012	1, 2
			Tesfaye, 2017	1, 2
			Tilahun and Aylate, 2015	1, 2
			Tolosa et al., 2009	1, 2
			Tolosa et al., 2013	1
			Tuke et al., 2017	1, 2
			Workineh et al., 2002	1, 2
			Wubishet et al., 2013	1, 2
			Yohannes and Alemu, 2018	1, 2
			Yohannis and Molla, 2013	1, 2
			Zenebe et al., 2014	1, 2
			Zeryehun and Abera, 2017	1, 2
			Zeryehun et al., 2013	1, 2
		Kenya	Maichomo et al., 2019	1
			Mureithi and Njuguna, 2016	1
			Mureithi et al., 2017	1
			Ndirangu et al., 2019	1
			Ndirangu et al., 2017	1, 2
			Ondiek et al., 2013	1
		Nigeria	Junaidu et al., 2011	1
			Shittu et al., 2012	1
			Suleiman et al., 2012	1
			Umaru et al., 2017	1, 2
		Rwanda	Iraguha et al., 2015	1
			Mpatswenumugabo et al., 2017	1
			Ndahetuye et al., 2019	1
		Seychelles	Watson et al., 1996	2
		South Africa	Brunner et al., 2019	2
		Sudan	Hamid et al., 2012	1, 2
		Tanzania	Kivaria et al., 2004	1, 2
			Mdegela et al., 2005	1
			Mdegela et al., 2009	1, 2
			Shem et al., 2001	1, 2
			Suleiman et al., 2013	1, 2
			Suleiman et al., 2017	1
		Uganda	Abrahmsén et al., 2014	1
			Björk, 2013	2
			Kasozi et al., 2014	1
			Ssajjakambwe et al., 2017	1
		Zambia	Eriksson, 2013	1
		Zimbabwe	Katsande et al., 2013	1, 2
			Perry et al., 1987	1
	Asia	Bangladesh	Badiuzzaman et al., 2015	1
			Bari et al., 2014	2
			Barua et al., 2014	1
			Biswas and Sarker, 2017	1
			Hoque et al., 2014	1
			Hoque et al., 2018	1, 2
			Hossain et al., 2016	1
			Islam et al., 2010	1, 2
			Islam et al., 2011	1
			Islam et al., 2014	1
			Kabir et al., 2017	1, 2
			Kayesh et al., 2014	1
			Meher et al., 2018	1
			Quaderi et al., 2013	1
			Rabbani and Samad, 2010	1
			Rahman et al., 2009	1
			Rahman et al., 2010	1
			Rahman et al., 2014	1
			Sarker et al., 2013	1
			Siddiqe et al., 2015	1
			Siddiquee et al., 2013	1
			Sumon et al., 2017	1
			Tripura et al., 2014	1
		China	Gao et al., 2017	2
			Li et al., 2009	1
			Memon et al., 2013	1, 2
			Wang et al., 2019	1
			Xu et al., 2015	1

(continued on next page)

Table 1 (*continued*)

No.	Continents	Countries	Studies [Author and Year]	SCM-1, CM-2
			Yang et al., 2014	1, 2
		Indonesia	Lucia et al., 2017	1
		Iran	Beheshti et al., 2011	1
			Haghkhah et al., 2010	1, 2
			Haghkhah et al., 2011	1
			Hashemi et al., 2011	1, 2
			Jamali et al., 2014	2
			Kalantari et al., 2013	1
			Marashifard et al., 2019	1
			Naghshineh et al., 2015	1
			Reza et al., 2011	1
		Iraq	Abdulkadhim, 2012	1
			Hussein, 2012	1
		Jordan	Alekish, 2015	1
			Hawari and Al-Dabbas, 2008	1, 2
		Malaysia	Othman and Bahaman, 2005	1
		Nepal	Dhakal, 2006	1
			Dhakal et al., 2007	1, 2
			Khanal and Pandit, 2013	1
			Shrestha and Bindari, 2012	1
		Pakistan	Ali et al., 2011	1
			Bachaya et al., 2005	1
			Bachaya et al., 2011	1
			Baloch et al., 2018	1, 2
			Chishty et al., 2007	2
			Farooq et al., 2008	1
			Hameed et al., 2012	1, 2
			Hussain et al., 2007	1, 2
			Hussain et al., 2013	1
			Khan and Muhammad, 2005	1, 2
			Khan et al., 2004	1, 2
			Khan et al., 2015	2
			Muhammad et al., 2010	1
			Mustafa et al., 2011	1, 2
			Qayyum et al., 2016	1
			Rafiullah et al., 2017	1
			Shahid et al., 2011	1
			Sharif and Ahmad, 2007	1
			Umar et al., 2013	1
		South Korea	Nam et al., 2010	1
			Sharma et al., 2013	1
		Sri Lanka	Sanotharan et al., 2016	1
		Thailand	Brunner et al., 2019	2
			Jarassaeng et al., 2012	1
			Suriyasathaporn, 2011	1
		Vietnam	Östensson et al., 2013	1
			Thanh et al., 2015	1, 2
	Europe	Austria	Graaf and Dwinger, 1996	1
		Croatia	Maćešić et al., 2016	1
		Denmark	Norberg et al., 2004	1, 2
		Estonia	Kalmus et al., 2006	2
		Finland	Pyörälä et al., 2011	1, 2
			Taponen et al., 2006	1, 2
		France	Botrel et al., 2010	1, 2
			Coulon et al., 2002	2
			Rupp and Boichard, 2000	2
		Germany	Schuberth et al., 2001	1, 2
		Greece	Fthenakis, 1998	1, 2
		Italy	Ceniti et al., 2017	2
		Kosovo	Sylejmani et al., 2016	1
		Netherlands	Borne et al., 2010	1, 2
			Miltenburg et al., 1996	2
			Sampimon et al., 2009	1
		Norway	Bakken, 1981	1
		Poland	Bochniarz and Wawron, 2012	2
			Bochniarz et al., 2013	1
			Hameed et al., 2006	1, 2
			Malinowski et al., 2003	2
			Sztachańska et al., 2016	1
		Serbia	Marija et al., 2016	1
			Zutic et al., 2012	1
		Slovakia	Idriss et al., 2013	1
		Spain	Reyes-Jara et al., 2016	2
		Sweden	Grönlund et al., 2005	1
			Hagnestam et al., 2007	2
			Shitandi and Kihumbu, 2004	1
		Turkey	Baştan et al., 2008	1
			Karahan and Çetinkaya, 2007	1
			Özenç et al., 2008	1
			Türkyilmaz et al., 2010	1, 2
		Ukraine	Brunner et al., 2019	2
		United Kingdom	Bradley and Green, 2001	2
			Bradley and Green, 2009	2
			Linton and Robinson, 1984	1, 2
	Latin America	Argentina	Brunner et al., 2019	2
			Dieser et al., 2014	1
			Gonzalez et al., 1980	1
		Bolivia	Edwards et al., 1982	1
		Brazil	Brunner et al., 2019	2
			Freitas et al., 2008	1, 2
			Rall et al., 2014	1
			Silva et al., 2013	1
			Vieira-da-Motta et al., 2001	1
		Chile	Brunner et al., 2019	2
		Colombia	Brunner et al., 2019	2
		Ecuador	Amer et al., 2018	1, 2
		Peru	Gómez-Quispe et al., 2015	1
		Trinidad and Tobago	Romain et al., 2000	1
		Uruguay	Gianneechini et al., 2002	1, 2
	North America	Canada	Lago et al., 2011	2
		Mexico	Brunner et al., 2019	2
			León-Galván et al., 2015	1, 2
			López et al., 2012	1, 2
			Olivares-Pérez et al., 2015	1
			Vázquez et al., 2013	1
		United States of America	Erskine et al., 2002	2
			Gonzalez et al., 1990	2
			Green et al., 2002	2
			Judge et al., 1997	2
			Morse et al., 1988	2
			Oliver and Mitchell, 1984	1
			Sargeant et al., 1998	2
			White et al., 1986	1, 2
			Wilson et al., 1997	1
			Wilson et al., 2007	2
			Zeng et al., 2009	1
			Gonzalez et al., 1989	2
			Pinzón-Sánchez and Ruegg, 2010	2
	Oceania	Australia	Daniel et al., 1982	2
			Plozza et al., 2011	1
			Stevenson, 2000	2
			Thompson and Houston, 1967	1
		New Zealand	Brunner et al., 2019	2
			Petrovski et al., 2009	2

on period-wise, zone-wise, state-wise, species-wise, and method-wise are given in Tables 7 and 8. The pooled prevalence estimate of SCM and CM in India were 45% [95% CI 40-49%, PI 11-84%] and 18% [95% CI 14-23%, PI 3-60%] obtained from 50,201 and 26,469 samples, respectively. The forest plot of the studies encompassed for SCM and CM prevalence estimates in India are given in Fig. 5 and Fig. 7. The period-wise scrutiny revealed a higher SCM and CM prevalence during 2011-19 when compared to past periods. The zone-wise and state-wise prevalence of SCM and CM in India are depicted in Figs. 6 and 8 respectively.

Table 2
Details of the mastitis prevalence studies from India included in the meta-analysis.

No.	Zones	Study states	Studies [Author and year]	SCM-1, CM-2
	North	Haryana	Bhanot et al., 2012	1
			Bulla et al., 2006	1
			Charaya et al., 2013	1
			Charaya et al., 2014	2
			Danish et al., 2018	1, 2
			Guha and Gera, 2011	1
			Guha et al., 2010	1
			Guha et al., 2012	1
			Jain et al., 2009	1
			Kumar and Sharma, 2002	1
			Kumar et al., 2007	1
			Panchal et al., 2016	1
			Pankaj et al., 2012	1
			Pankaj et al., 2013	1
			Sharma and Sindhu, 2007	1, 2
			Sharma et al., 2006	1
			Sharma et al., 2012	1
			Sharma et al., 2018a	1, 2
			Sharma et al., 2018b	1
			Sindhu et al., 2009	1
			Sindhu et al., 2012	1
			Thakur et al., 2018	1
			Jingar et al., 2017	2
		Himachal Pradesh	Kaur et al., 2015a	1
		Jammu and Kashmir	Ashraf et al., 2018	1
			Bhat et al., 2016	1
			Bhat et al., 2017	2
			Dar et al., 2014	1
			Qadri et al., 2017	1
			Sanjolly et al., 2017	1, 2
			Sharma et al., 2010b	1, 2
			Sharma et al., 2018c	1, 2
			Sudhan et al., 2005	1
			Tufani et al., 2012	1
		Punjab	Bansal et al., 2015	1
			Kaur et al., 2015b	1
			Mir et al., 2014	1
			Prabhakar et al., 1995	2
		Uttar Pradesh	Ali et al., 2015	1
			De and Reena, 2009	1, 2
			Pachauri et al., 2013	1, 2
			Prakash et al., 2013	1, 2
			Sharma et al., 2015	1, 2
			Singh et al., 2018	1
			Tyagi et al., 2013	1
			Verma et al., 2018	1
		Uttarakhand	Karabasanavar and Singh, 2013	1
			Mahajan et al., 2011	2
			Tripathi et al., 2018	1
	East	Andaman and Nicobar	Sunder et al., 2013	1
		Assam	Gogoi et al., 2017	1
			Sharma and Brinty, 2014	1
		Bihar	Hardenberg, 2016	1, 2
		Mizoram	Das et al., 2015	1
			Deka et al., 2013	1, 2
		Sikkim	Dubal et al., 2010	1,2
		West Bengal	Banerjee et al., 2017	1
			Pranay et al., 2017	1
	West	Gujarat	Bhanderi and Garg, 2012	1
			Bhatt et al., 2011	1, 2
			Devgania et al., 2015	1
			Kathiriya et al., 2014	1
			Patel and Trivedi, 2015	1
			Patel et al., 2012	1
			Patel et al., 2017	1, 2
			Thakor and Patel, 2013	1
		Maharashtra	Bhikane et al., 2010	1
			Chougule et al., 2014	2
			Joshi and Gokhale, 2006	1
			Shaikh et al., 2018	1, 2
			Swami et al., 2017	1
		Rajasthan	Chahar et al., 2005	1
			Jena et al., 2015	1
			Joshi et al., 2013	1
			Langer et al., 2014	1
			Savita et al., 2018	1
			Sharma et al., 2010a	1
	South	Andhra Pradesh	Kavitha et al., 2009	1
			Manasa et al., 2019	1, 2
			Ramachandraiah et al., 1998	1
			Reddy et al., 2015	1
		Karnataka	Harini and Sumathi, 2011	1
			Hegde et al., 2013	1
			Jagadeesh et al., 2016	1
			Kaliwal et al., 2011	1, 2
			Krishnaveni et al., 2014	1, 2
			Kurjogi and Kaliwal, 2011	1, 2
			Kurjogi and Kaliwal, 2014	1, 2
			Prabhu et al., 2015	1, 2
			Preethirani et al., 2015	1
			Sadashiv and Kaliwal, 2013	1, 2
			Sundareshan et al., 2014	1
			Swamy and Krishnamurthy, 1998	1
		Kerala	Lakshmi and Jayavardhanan, 2016	1, 2
		Tamil Nadu	Ayyappadas and Renugadevi, 2013	2
			Balaji and Saravanan, 2017	1
			Balaji and Senthilkumar, 2017	1
			Elango et al., 2010	1
			Mubarack et al., 2012	1, 2
			Nithya et al., 2017	1
			Selvaraju et al., 2013	1
			Srinivasan et al., 2013	1
			Subramanian et al., 2019	1, 2
			Sukumar and James, 2012	2
			Suresh et al., 2017	2
			Visvanath et al., 2012	2
		Telangana	Dasohari et al., 2017	1
	Central	Chhattisgarh	Kashyap et al., 2019	1
			Neelesh and Maiti, 2010	1
			Ottalwar et al., 2018	1
			Sharma et al., 2007	1
			Vishwakarma et al., 2010	1
		Madhya Pradesh	Shrivastava et al., 2017	1, 2

The SCM and CM prevalence in India was higher in the Central zone when compared to other zones. Based on state-wise breakdown shown the highest SCM prevalence in West Bengal [75%] followed by Mizoram [65%], Chhattisgarh [63%], Karnataka [58%], and other states. The CM prevalence was high in Andhra Pradesh [44%], Madhya Pradesh [38%], Haryana [31%] followed by the other twelve states in India, and was low in Gujarat [6%] and Maharashtra [6%] states. The cattle species revealed a higher SCM prevalence of 49% than the buffaloes [32%], but for CM prevalence no difference between cattle and buffaloes was observed. The maximum number of studies [85] on SCM prevalence in India employed CMT and indicated SCM prevalence was 43%. By using SCC, the SCM prevalence was 39% and 46% was observed by other methods combined. The method-wise analysis revealed CM prevalence by the CE method and other methods was the same [18%]. The SCM prevalence studies from India included for meta-analysis revealed highly significant ($P<0.01$) difference based period-wise, zone-wise, state-wise, species-wise, and method except for the Assam state, which showed no significant difference. The Cochran Q statistics of CM prevalence studies indicated a highly significant ($P<0.01$) difference, which showed the heterogeneity between the studies, except for Maharashtra

Table 3
Subclinical Mastitis (SCM) prevalence estimates in the World based on meta-analysis

No.	Parameters	Period	Number of studies	Total samples	Prevalence (%) [CI at 95% level]	PI (%) at 95% level	Tests for heterogeneity			
							I^2 Value (%)	Tau square value	Degrees of Freedom	Cochran Q value
1.	SCM in World	1967-2019	222	2,51,372	42 [38-45]	10-83	99.4	0.931	221	26318.4**
Year-wise										
1.	SCM in World-I	1967-2000	13	1,61,708	40 [27-55]	5-89	99.9	1.157	12	6664.5**
2.	SCM in World-II	2001-2010	54	22,794	38 [31-45]	6-86	98.9	1.379	53	6118.4**
3.	SCM in World-III	2011-2019	155	66,870	43 [40-47]	12-80	98.4	0.739	154	12414.3**
Continent-wise										
1.	SCM in Africa	1987-2019	108	30,324	44 [40-49]	10-84	98.2	0.941	107	4941.7**
2.	SCM in Asia	2004-2019	69	34,491	42 [37-47]	10-82	98.7	0.861	68	7111.5**
3.	SCM in Europe	1981-2016	25	49,209	37 [29-47]	8-80	99.4	0.908	24	2485.7**
4.	SCM in Latin America	1980-2018	11	14,913	34 [17-56]	2-92	99.8	2.391	10	5117.7**
5.	SCM in North America	1984-2015	8	1,10,449	46 [35-56]	15-80	99.2	0.364	7	571.6**
6.	SCM in Oceania	1967 & 2011	2	11,811	36 [21-54]	-	98.1	0.283	1	100.9**
Period-wise										
1.	SCM in Africa-I	1987&2000	2	426	79 [54-93]	-	93.4	0.678	1	28.2**
2.	SCM in Africa-II	2002-2019	106	29,898	43 [39-48]	11-83	98.1	0.897	105	4594.1**
3.	SCM in Asia-II	2004-2019	68	34,463	41 [36-47]	10-81	98.7	0.835	67	7086.3**
4.	SCM in Europe-I	1981-1998	4	38,112	21 [14-30]	9-43	98.4	0.213	3	117.8**
5.	SCM in Europe-II	2001-2016	21	11,097	41 [32-51]	9-82	98.9	0.891	20	2141.9**
6.	SCM in Latin America-I	1980-2000	3	5,435	44 [23-67]	10-84	99.2	0.726	2	548.0**
7.	SCM in Latin America-II	2001-2018	8	9,478	30 [12-58]	1-94	99.7	2.923	7	3857.7**
8.	SCM in North America-I	1984-1997	3	1,06,306	47 [35-59]	0-100	98.2	0.184	2	58.0**
9.	SCM in North America-II	2008-2015	5	4,143	45 [31-60]	16-78	98.0	0.466	4	340.9**
Species-wise										
1.	SCM in Cattle	1967-2019	206	2,42,176	42 [39-45]	10-83	99.4	0.912	205	23489.9**
2.	SCM in Buffaloes	2005-2018	26	8,762	46 [34-57]	7-90	98.7	1.474	25	3025.6**
Method-wise										
1.	SCM by CMT	1980-2019	185	1,14,114	43 [39-46]	10-83	99.0	0.918	184	15121.9**
2.	SCM by SCC	1987-2017	29	1,19,028	46 [36-56]	9-88	99.5	1.193	28	4924.2**
3.	SCM by SFMT	2005-2018	16	5,480	41 [31-52]	10-81	98.1	0.792	15	791.6**
4.	SCM by WST	2008-2018	10	3,360	37 [29-46]	16-65	95.7	0.320	9	199.8**

Note: CI-Confidence Interval, PI-Prediction Interval, CMT-California Mastitis Test, SCC-Somatic Cell Count, SFMT-Surf Field Mastitis Test, WST-White Slide Test, *-Significant (P<0.05), **- Highly significant (P<0.01).

state showed significant (P<0.05) difference and no significant difference for East and West zone, Gujarat state established from the subgroup analysis.

4. Discussion

The studies on SCM and CM prevalence retrieved for this study, from various countries in the World will serve as compiled baseline information at one place for researchers across countries and appropriate stakeholders. In the present report, the SCM and CM prevalence estimates of dairy cows in the World were obtained based on a meta-analysis. The number of studies on SCM prevalence was more than CM from the World and necessitates the importance of SCM in dairying. This might be due to fact that the SCM is not grossly detectable in milk and requires a diagnostic test, so many researchers are working on this, at early detection in dairy animals. More studies on SCM [155] and CM [88] prevalence were reported during 2011-19 signifying the importance of mastitis in dairy animals in the World during the current times. The number of prevalence studies on SCM and CM was increasing in recent durations and may be attributable to the awareness among the dairy farmers about the quality of milk, which will help them in fetching a good price for the milk produced. Further, the mastitis prevalence studies showed high heterogeneity between the studies included for meta-analysis. This may be owing to various factors comprising of parity of cattle, stage of lactation and genetic breed characters, agroclimatic conditions, weather conditions and practices followed in the management of dairy farms (Joshi and Gokhale, 2006). More SCM studies were reported from the Africa continent than other continents, highlighting the SCM problem there and concurred with a previous report (Abebe et al., 2016). Among African countries, more number of studies was reported from Ethiopia, suggesting mastitis as a major problem in dairy animals due to underdeveloped country. Further, the mastitis studies reported from 61 countries of the World included in this study with more number of countries from the European continent i.e., twenty countries, which suggests the availability of mastitis diagnostic facilities in these countries.

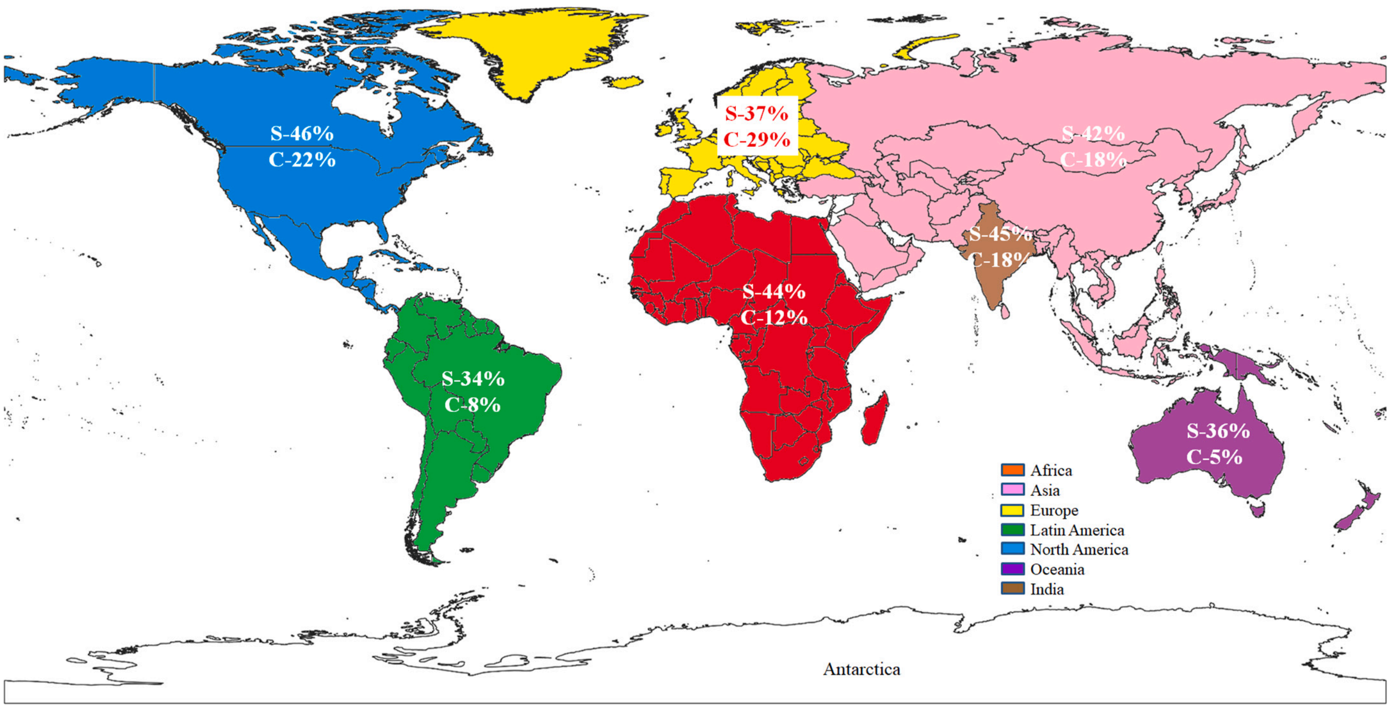

Fig. 4. World map showing prevalence estimates for Subclinical (S) and Clinical (C) mastitis in dairy cattle and buffaloes.

The prevalence estimates were 42% and 15% for SCM and CM in the World and SCM showed the highest prevalence when compared to CM. This indicated the importance of SCM than CM in dairy cattle and buffaloes in the World. In India, the estimated prevalence of SCM was 46.35% obtained from the meta-analysis of studies described during the period 1995-2014 as reported (Bangar et al., 2015) and it was high when compared to the present study. A study reported the SCM prevalence was ranging from 15 to 75 % on a cow basis (Cynthia, 2005) and concurred with the present study. The SCM prevalence estimate was in agreement with the results reported earlier for Bangladesh (Rahman et al., 2010) and Sri Lanka (Sanotharan et al., 2016). However, SCM prevalence was 29.5% (Islam et al., 2011) and 20.2% (Sarker et al., 2013) in Bangladesh as previously reported and considered low compared to this study. The SCM prevalence was higher of late, signifying the need for prevention and control of the same in dairy animals, and might be due to more awareness among the farmers on mastitis. Further, the high prevalence of SCM may be attributed to the low udder immunity in old cows and buffaloes, rearing animals with pendulous udders, and lack of genetic selection of dairy cattle with suitable confirmation of udder for infection prevention as reported (Ahmed et al., 2018). The prevalence estimate was higher in the Africa continent and might be attributed to the lack of implementation of mastitis prevention and control practices by the herd owners in the dairy farms in these African countries as discussed earlier (Abebe et al., 2016). The cattle showed SCM prevalence lesser than the buffaloes and were found to be divergent with a previous study which specified 36% in crossbred cows and 27% in buffaloes in Pakistan (Khan and Muhammad, 2005). In the same way, SCM prevalence was 33% in cows and 8% in buffaloes (Hussain et al., 1984) and differs from the present study. However, Bachaya et al. (2011) described that variations in the SCM prevalence might be due to differences in management practices, diagnostic methods, breed of the animals, immune response, and prevailing climatic conditions in the particular geographical locations. Method-wise breakdown revealed high SCM prevalence by SCC [46%] and low by WST [37%]. Inflammation of the mammary gland increases the number of somatic cells in milk (Bachaya et al., 2011) and thereby increases the SCC in SCM and CM cases. Thus, the SCC method may be employed for the detection of SCM in dairy cows, but the most commonly followed method for the detection of SCM was CMT and employed in the majority of SCM prevalence studies due to ease of usage in field conditions. However, the SCC may be utilized in the future for accurate diagnosis of SCM in dairy animals, for improved diagnosis and prevention of milk loss due to SCM.

The CM prevalence estimate was 15%, which was less when compared to the SCM, indicating the importance of SCM in the World. The reason may be the easy detection of CM with the physical examination of milk and difficulty in SCM detection, which shows no changes in the milk. Similarly, CM prevalence was reported among dairy cattle in Ethiopia [12.5%] (Zeryehun and Abera, 2017), India [11.5%] (Bhat et al., 2017), and China [3.3%] (Gao et al., 2017) was low in comparison to this study. The year-wise examination indicated the decreasing of CM prevalence in the World over the times and might be due to the awareness among the farmers on CM and easy detection of the same by farmers themselves. In this study, CM prevalence was high in Europe and low in Oceania in comparison to other continents except for Antarctica. The explanations for high prevalence in Europe require further investigation and organisms causing the CM may be different from the other continents, herd-specific factors, milk sampling, and difficult to compare data across dairy farms, regions, and countries as discussed earlier (Brunner et al., 2019). The buffaloes revealed higher CM prevalence than cattle and resulted in the importance of CM in buffaloes in the World. The reason for this might be due to the poor management of

Table 4
Clinical Mastitis (CM) prevalence estimates in the World based on meta-analysis

No.	Parameters	Period	Number of studies	Total samples	Prevalence (%) [CI at 95% level]	PI (%) at 95% level	Tests for heterogeneity			
							I^2 Value (%)	Tau square value	Degrees of Freedom	Cochran Q value
1.	CM in World	1982-2019	150	1,10,066	15 [12-19]	1-81	99.4	2.524	149	29934.3**
Year-wise										
1.	CM in World-I	1982-2000	16	43,442	29 [14-53]	1-97	99.9	3.902	15	7614.3**
2.	CM in World-II	2001-2010	46	25,087	18 [12-27]	1-85	99.4	2.564	45	6293.1**
3.	CM in World-III	2011-2019	88	41,537	12 [9-16]	1-70	98.7	2.024	87	15671.8**
Continent-wise										
1.	CM in Africa	1996-2019	78	26,616	12 [9-15]	1-62	97.8	1.544	77	3978.0**
2.	CM in Asia	2004-2019	25	21,840	18 [10-31]	1-89	99.5	2.966	24	10841.4**
3.	CM in Europe	1988-2019	22	38,976	29 [16-46]	1-95	99.8	3.131	21	4985.2**
4.	CM in Latin America	2002-2019	7	3,581	8 [3-19]	1-75	98.0	1.668	6	1123.6**
5.	CM in North America	1986-2019	14	13,965	22 [9-45]	0-97	99.7	4.213	13	6327.7**
6.	CM in Oceania	1982-2019	3	4,771	5 [1-21]	0-99	98.9	2.109	2	437.5**
Period-wise										
1.	CM in Africa-I	1996-2000	3	5,338	7 [2-29]	0-66	98.8	1.968	2	330.6**
2.	CM in Africa-II	2002-2019	75	21,278	12 [9-15]	1-61	97.7	1.157	74	3107.0**
3.	CM in Asia-II	2004-2019	24	18,075	19 [10-32]	1-90	99.5	3.095	23	10608.2**
4.	CM in Europe-I	1984-1999	5	29,902	39 [12-74]	1-99	99.9	2.808	4	729.4**
5.	CM in Europe-II	2001-2019	17	9,704	26 [13-46]	1-94	99.6	3.180	16	2450.3**
6.	CM in Latin America-II	2002-2019	7	3,581	8 [3-19]	1-75	98.0	1.668	6	1123.6**
7.	CM in North America-I	1986-1998	6	6,421	49 [15-84]	1-99	99.8	4.526	5	3318.2**
8.	CM in North America-II	2002-2019	8	7,544	10 [4-24]	1-82	99.2	2.043	7	985.8**
9.	CM in Oceania-I	1982 & 2000	2	1,781	13 [8-19]	-	82.8	0.095	1	13.1**
Species-wise										
1.	CM in Cattle	1982-2019	143	1,06,181	14 [11-18]	1-79	99.4	2.446	142	28203.7**
2.	CM in Buffaloes	2004-2018	15	3,744	28 [14-47]	1-94	99.0	2.657	14	1199.2**
Method-wise										
1.	CM by CE	1982-2019	146	1,07,177	15 [12-19]	1-80	99.4	2.467	145	28743.9**
2.	CM by OT	2002-2014	4	2,700	13 [2-50]	1-99	99.1	3.816	3	1023.7**

Note: CI-Confidence Interval, PI-Prediction Interval, CE-Clinical Examination, *- Significant (P<0.05), **- Highly significant (P<0.01).

Table 5
Subclinical Mastitis (SCM) prevalence estimates in various countries in the World based on meta-analysis.

No.	Parameters	Period	Number of studies	Total samples	Prevalence (%) [CI at 95% level]	PI (%) at 95% level	Tests for heterogeneity			
							I^2 Value (%)	Tau square value	Degrees of Freedom	Cochran Q value
	Algeria	2013-2018	3	559	46 [31-61]	21-73	91.6	0.265	2	32.1**
	Argentina	1980&2013	2	6,464	56 [54-58]	-	68.9	0.003	1	6.5*
	Australia	1967&2011	2	11,811	36 [21-54]	-	98.1	0.283	1	100.9**
	Austria	1996	1	2,186	24	-	-	-	-	-
	Bangladesh	2009-2018	22	5,363	45 [37-52]	16-77	96.3	0.518	21	687.2**
	Bolivia	1982	1	1,090	19	-	-	-	-	-
	Brazil	2001-2014	4	3,122	27 [11-53]	3-81	99.2	1.197	3	833.5**
	China	2009-2015	5	4,434	39 [26-53]	6-87	98.7	0.449	4	427.5**
	Croatia	2016	1	1,549	49	-	-	-	-	-
	Denmark	2004	1	322	45	-	-	-	-	-
	Ecuador	2018	1	250	60	-	-	-	-	-
	Egypt	2009-2018	15	4,319	41 [30-53]	8-84	97.8	0.829	14	912.0**
	Ethiopia	2002-2019	63	19,806	40 [35-45]	12-76	97.7	0.639	62	2273.0**
	Finland	2006&2011	2	367	54 [48-61]	-	29.0	0.010	1	2.9^{NS}
	France	2010	1	1,770	53	-	-	-	-	-
	Germany	2001	1	68	57	-	-	-	-	-
	Greece	1998	1	172	22	-	-	-	-	-
	Indonesia	2017	1	28	82	-	-	-	-	-
	Iran	2009-2019	8	8,613	32 [22-44]	7-75	98.2	0.521	7	211.8**
	Iraq	2012	2	472	50 [36-64]	-	79.1	0.131	1	9.9*
	Jordan	2008&2015	2	353	44 [27-62]	-	91.0	0.264	1	22.7**
	Kenya	2013-2019	6	734	37 [20-57]	2-92	96.2	1.001	5	98.1**
	Kosovo	2016	1	156	26	-	-	-	-	-
	Malaysia	2005	1	60	82	-	-	-	-	-
	Mexico	2012-2015	4	4,042	43 [27-61]	2-96	98.6	0.542	3	340.0**
	Nepal	2006-2013	4	818	22 [8-49]	1-99	97.2	1.510	3	191.4**
	Nigeria	2011-2017	4	1,999	39 [29-50]	7-83	93.8	0.178	3	52.7**
	Netherlands	2009&2010	2	436	24 [20-28]	-	0.0	0.0	1	2.66^{NS}
	Norway	1981	1	35,464	31	-	-	-	-	-
	Pakistan	2005-2018	17	11,992	42 [30-55]	6-88	99.3	1.197	16	4162.2**
	Peru	2015	1	459	72	-	-	-	-	-
	Poland	2006-2016	3	1,314	30 [25-36]	2-91	77.8	0.042	2	15.4**
	Rwanda	2015-2019	3	574	60 [46-74]	32-83	91.4	0.259	2	38.5**
	Serbia	2012&2016	2	1,397	25 [19-32]	-	84.5	0.051	1	12.7**
	Slovakia	2013	1	390	74	-	-	-	-	-
	South Korea	2010&2013	2	895	55 [52-58]	-	0.0	0.0	1	0.7^{NS}
	Sri Lanka	2016	1	152	43	-	-	-	-	-
	Sudan	2012	1	60	23	-	-	-	-	-
	Sweden	2004&2005	2	403	74 [55-87]	-	92.5	0.344	1	27.3**
	Tanzania	2000-2017	6	959	61 [40-78]	6-97	96.6	1.061	5	151.7**
	Thailand	2011&2012	2	353	35 [30-40]	-	0.0	0.0	1	1.7^{NS}
	Trinidad and Tobago	2000	1	177	60	-	-	-	-	-
	Turkey	2007-2010	4	2,925	30 [11-60]	1-99	99.3	1.664	3	852.3**
	Uganda	2014-2017	3	390	85 [81-88]	17-99	34.3	0.033	2	4.9^{NS}
	United Kingdom	1984	1	290	11	-	-	-	-	-
	Uruguay	2002	1	3,351	1	-	-	-	-	-
	United States of America	1984-2008	4	1,06,407	49 [39-58]	13-86	96.9	0.147	3	59.4**
	Vietnam	2016&2015	2	1,001	52 [36-67]	-	96.2	0.216	1	53.8**
	Zambia	2013	1	111	49	-	-	-	-	-
	Zimbabwe	1987&2013	2	945	57 [8-95]		99.4	3.635	1	540.6**

Note: CI-Confidence Interval, PI-Prediction Interval, NS-Non significant, *- Significant ($P<0.05$), **- Highly significant ($P<0.01$).

Table 6
Clinical Mastitis (CM) prevalence estimates in various countries in the World based on meta-analysis

No.	Parameters	Period	Number of studies	Total samples	Prevalence (%) [CI at 95% level]	PI (%) at 95% level	Tests for heterogeneity			
							I^2 Value (%)	Tau square value	Degrees of Freedom	Cochran Q value
1.	Algeria	2018	1	222	6	-	-	-	-	-
2.	Argentina	2019	1	720	5	-	-	-	-	-
3.	Australia	1982 & 2000	2	1,781	13 [8-19]	-	82.8	0.095	1	13.1**
4.	Bangladesh	2010-2018	4	1,362	8 [3-22]	1-96	95.9	1.414	3	59.8**
5.	Brazil	2008, 2019	2	1,192	3 [1-10]	-	91.7	0.952	1	23.2**
6.	Canada	2011	1	214	22	-	-	-	-	-
7.	Chile	2019	1	159	9	-	-	-	-	-
8.	China	2012-2016	3	4,863	34 [5-85]	0-98	99.8	4.332	2	3210.9**
9.	Colombia	2019	1	183	5	-	-	-	-	-
10.	Denmark	2004	1	322	81	-	-	-	-	-
11.	Ecuador	2018	1	250	12	-	-	-	-	-
12.	Egypt	2010-2015	10	2,721	22 [10-43]	1-92	98.5	2.409	9	815.7**
13.	Estonia	2006	1	2,355	13	-	-	-	-	-
14.	Ethiopia	2002-2019	55	15,822	9 [7-12]	2-41	96.0	0.908	54	1338.5**
15.	Finland	2006 & 2011	2	367	45 [40-52]	-	29.0	0.010	1	2.9^{NS}
16.	France	1999-2010	3	22,604	30 [15-50]	7-70	99.6	0.563	2	1118.9**
17.	Germany	2001	1	68	43	-	-	-	-	-
18.	Greece	1998	1	172	17	-	-	-	-	-
19.	Iran	2006-2014	4	6,738	13 [2-49]	0-90	99.1	3.413	3	562.8**
20.	Italy	2017	1	110	47	-	-	-	-	-
21.	Jordan	2008	1	220	16	-	-	-	-	-
22.	Kenya	2017	1	50	54	-	-	-	-	-
23.	Mexico	2012-2019	3	2,864	3 [1-12]	0-34	96.6	1.416	2	109.4**
24.	Nepal	2007	1	355	6	-	-	-	-	-
25.	Netherlands	1996 & 2010	2	9,391	21 [10-39]	-	98.4	0.388	1	110.8**
26.	New Zealand	2009 & 2019	2	6,755	3 [0-25]	-	99.0	2.652	1	546.2**
27.	Nigeria	1999 & 2017	2	5,360	2 [2-3]	-	0.0	0.0	1	1.36^{NS}
28.	Pakistan	2004-2018	8	3,794	19 [10-33]	2-77	98.7	1.066	7	371.0**
29.	Poland	2003-2012	3	1,007	4 [1-23]	0-67	95.9	2.974	2	77.4**
30.	Seychelles	1996	1	273	35	-	-	-	-	-
31.	South Africa	2019	1	764	37	-	-	-	-	-
32.	Spain	2016	1	327	33	-	-	-	-	-
33.	Sudan	2012	1	60	77	-	-	-	-	-
34.	Sweden	2007	1	506	59	-	-	-	-	-
35.	Tanzania	2000-2013	5	818	19 [7-46]	1-97	97.7	1.885	4	152.8**
36.	Thailand	2019	1	83	1	-	-	-	-	-
37.	Turkey	2010	1	244	50	-	-	-	-	-
38.	Uganda	2013	1	138	13	-	-	-	-	-
39.	Ukraine	2019	1	164	1	-	-	-	-	-
40.	United Kingdom	1984-2015	4	1,570	74 [64-81]	27-95	90.9	0.158	3	43.9**
41.	United States of America	1986-2007	10	10,887	35 [14-64]	1-98	99.8	3.729	9	5015.5**
42.	Uruguay	2002	1	1,077	52	-	-	-	-	-
43.	Vietnam	2015	1	550	22	-	-	-	-	-
44.	Zimbabwe	2016	1	584	5	-	-	-	-	-

Note: CI-Confidence Interval, PI-Prediction Interval, ^{NS}-Non significant, **- Highly significant ($P<0.01$).

Table 7
Subclinical mastitis (SCM) prevalence estimates in India based on period-wise, zone-wise, states-wise, species-wise and method-wise.

No.	Parameters	Period	Number of studies	Total samples	Prevalence (%) [CI at 95% level]	PI (%) at 95% level	Tests for heterogeneity			
							I^2 Value (%)	Tau square value	Degrees of Freedom	Cochran Q value
1.	SCM in India	1998-2019	103	50,201	45 [40-49]	11-84	98.8	0.863	102	7172.1**
2a.	SCM in India-Period I	1998-2010	25	12,238	42 [33-53]	8-87	98.8	1.056	24	1743.9**
2b.	SCM in India-Period II	2011-2019	78	37,963	46 [41-51]	12-83	98.7	0.802	77	5337.7**
3.	SCM in North zone	2002-2018	44	25,522	40 [33-47]	8-83	99.0	0.938	43	4890.8**
3a.	Haryana	2002-2018	21	18,970	35 [26-44]	7-80	99.3	0.892	20	3692.6**
3b.	Himachal Pradesh	2015	1	935	44	-	-	-	-	-
3c.	Jammu and Kashmir	2005-2018	9	3,041	47 [32-62]	8-90	98.1	0.854	8	682.9**
3d.	Punjab	2014 & 2015	3	1,277	30 [14-52]	0-99	97.5	0.665	2	129.7**
3e.	Uttarakhand	2013 & 2018	2	292	39 [20-62]	-	92.9	0.429	1	28.4**
3f.	Uttar Pradesh	2009-2018	8	1,007	49 [31-67]	6-94	96.4	1.108	7	149.2**
4.	SCM in East zone	2010-2017	9	1,675	48 [30-67]	5-94	97.7	1.326	8	449.0**
4a.	Andaman & Nicobar	2013	1	25	12	-	-	-	-	-
4b.	Assam	2014 & 2017	2	213	27 [17-40]	-	71.0	0.129	1	7.2^{NS}
4c.	Bihar	2016	1	313	35	-	-	-	-	-
4d.	Mizoram	2013 & 2015	2	60	65 [17-94]	-	87.0	2.245	1	21.3**
4e.	Sikkim	2010	1	276	25	-	-	-	-	-
4f.	West Bengal	2017	2	788	75 [46-91]	-	98.0	0.798	1	112.2**
5.	SCM in West zone	2005-2019	18	14,279	41 [33-50]	12-77	97.6	0.531	17	588.8**
5a.	Gujarat	2011-2016	8	11,796	33 [23-45]	8-76	96.7	0.484	7	296.3**
5b.	Maharashtra	2006-2019	4	1,199	38 [27-50]	6-85	90.6	0.209	3	46.4**
5c.	Rajasthan	2013-2019	7	734	37 [20-57]	6-83	92.1	0.387	6	161.6**
6.	SCM in South zone	1998-2019	26	5,319	51 [43-59]	16-85	96.6	0.633	25	549.9**
6a.	Andhra Pradesh	1998-2019	4	732	30 [15-53]	0-98	95.7	0.865	3	104.0**
6b.	Karnataka	1998-2016	12	3,081	58 [49-67]	24-86	95.8	0.394	11	241.2**
6c.	Kerala	2016	1	80	35	-	-	-	-	-
6d.	Tamil Nadu	2010-2019	8	1,290	51 [39-63]	15-86	94.4	0.478	7	143.8**
6e.	Telangana	2017	1	136	66	-	-	-	-	-
7.	SCM in Central zone	2007-2019	6	3,406	63 [49-75]	17-94	98.0	0.510	5	438.6**
7a.	Chhattisgarh	2007-2018	5	3,321	63 [46-77]	10-96	98.6	0.606	4	436.3**
7b.	Madhya Pradesh	2017	1	85	62	-	-	-	-	-
8a.	SCM in Cattle	1998-2019	81	39,294	49 [44-53]	14-84	98.6	0.747	80	5716.7**
8b.	SCM in Buffaloes	1998-2019	30	10,907	32 [25-39]	6-76	98.1	0.839	29	934.5**
9a.	SCM by CMT	1998-2019	85	34,929	43 [38-47]	12-80	98.3	0.721	84	4889.4**
9b.	SCM by SCC	2006-2019	34	8,712	39 [31-48]	7-85	98.1	1.112	33	2165.4**
9c.	SCM by Other methods	1998-2018	19	13,639	46 [35-57]	10-87	99.0	0.905	18	858.9**

Note: CI-Confidence Interval, PI-Prediction Interval, CMT-California Mastitis Test, NS-Not significant, **- Highly Significant ($P<0.01$).

buffaloes than cows in many countries in the World. In contrast, there is a notion that the buffaloes are resistant to infection due to tight streak canal surrounded by tight muscles and also less population restricted to few continents in the World, with more of the nondescript breed of buffaloes are being reared. Method-wise subgroup analysis revealed a higher CM prevalence by clinical examination and the most commonly used method for CM diagnosis than other methods and concurred with an earlier report (Tuke et al., 2017).

The countrywide SCM prevalence was high in Uganda [85%] and low in Uruguay [1%]. The possible explanations for the high prevalence in Uganda could be attributed to the risk factors for SCM prevalence were restriction of cows without grazing, poor udder hygiene practices, and more fraction of cows in late parity and late stages of lactation as described earlier (Abrahmsén et al., 2014). The low SCM prevalence in Uruguay was attributed to the ecological influence on the occurrence of mastitis as discussed earlier (Gianneechini et al., 2002). Countrywide breakdown suggested high CM prevalence in the United Kingdom and low in Brazil, New Zealand countries in the World based on meta-analysis was observed. The possible reasons for high prevalence in the United Kingdom could be the reliability of identification and detection of CM cases by the herdsman because they were well-motivated and with improved awareness of mastitis throughout the study as reported (Bradley and Green, 2001). Petrovski et al. (2009) stated that the number of cows included in the analysis and cows with CM was less in number in the farms sampled in New Zealand as indicated, which might be the reason for low prevalence. Further, fewer studies were available for inclusion in a meta-analysis from Brazil and New Zealand may be the reason for low CM prevalence compared to other countries.

The overall SCM prevalence estimate in India was 45%, and was in agreement with previous studies reported based on meta-analysis were 46.35% (Bangar et al., 2015) and 41% (Krishnamoorthy et al., 2017). In recent times, the SCM prevalence was high during 2011-19 in contrast with 1998-2010. This could be due to better diagnostic methods and awareness of SCM by the dairy farmers. Bangar et al. (2015) indicated that the high SCM prevalence over recent years could be attributed as the principal cause for the low milk productivity of dairy cattle and buffaloes in India. Among the studies, more numbers were from North and South zones in India, which may perhaps be due to the presence of

Table 8
Clinical mastitis (CM) prevalence estimates in India based on period-wise, zone-wise, states-wise, species-wise and method-wise.

No.	Parameters	Period	Number of studies	Total samples	Prevalence (%) [CI at 95% level]	PI (%) at 95% level	Tests for heterogeneity			
							I^2 Value (%)	Tau square value	Degrees of Freedom	Cochran Q value
1.	CM in India	1995-2019	37	26,469	18 [14-23]	3-60	98.8	0.847	36	1900.4**
2a.	CM in India-Period I	1995-2010	5	6,759	15 [12-19]	7-31	78.8	0.065	4	27.3**
2b.	CM in India-Period II	2011-2019	32	19,710	19 [14-25]	3-64	98.8	0.969	31	1702.6**
3.	CM in North zone	1995-2018	15	21,834	19 [13-27]	3-62	99.4	0.726	14	980.3**
3a.	Haryana	2007-2018	5	14,010	31 [20-45]	4-81	99.4	0.421	4	604.9**
3b.	Jammu and Kashmir	2010-2018	4	1,165	10 [5-19]	0-74	92.0	0.417	3	21.6**
3c.	Punjab	1995	1	421	9	-	-	-	-	-
3d.	Uttarakhand	2011	1	5,698	21	-	-	-	-	-
3e.	Uttar Pradesh	2009-2015	4	540	21 [11-36]	1-90	89.2	0.513	3	30.4**
4.	CM in East zone	2010-2016	3	601	14 [11-18]	2-54	12.8	0.007	2	3.0^{NS}
4a.	Bihar	2016	1	285	12	-	-	-	-	-
4b.	Mizoram	2013	1	40	17	-	-	-	-	-
4c.	Sikkim	2010	1	276	25	-	-	-	-	-
5.	CM in West zone	2011-2019	4	1,472	6 [5-7]	4-9	0.0	0.0	3	4.6^{NS}
5a.	Gujarat	2011 & 2016	2	654	6 [4-8]	-	0.0	0.0	1	0.18^{NS}
5b.	Maharashtra	2014 & 2019	2	818	6 [5-8]	-	0.0	0.0	1	4.4*
6.	CM in South zone	2011-2019	14	2,477	22 [14-32]	3-71	95.8	0.929	13	509.4**
6a.	Andhra Pradesh	2019	1	61	44	-	-	-	-	-
6b.	Karnataka	2011-2015	6	1,269	18 [9-33]	1-82	96.1	1.011	5	292.3**
6c.	Kerala	2016	1	80	24	-	-	-	-	-
6d.	Tamil Nadu	2012-2019	6	1,067	23 [12-40]	2-84	95.8	0.925	5	204.2**
7.	CM in Central zone	2017	1	85	38	-	-	-	-	-
7a.	Madhya Pradesh	2017	1	85	38	-	-	-	-	-
8a.	CM in Cattle	2007-2019	32	20,319	19 [14-24]	4-58	98.5	0.762	31	1350.5**
8b.	CM in Buffaloes	1995-2019	12	6,150	19 [11-30]	2-75	98.9	1.209	11	636.2**
9a.	CM by CE	1995-2019	30	18,664	18 [14-25]	3-64	98.7	0.997	29	1653.7**
9b.	CM by Other methods	2007-2018	7	7,805	18 [13-24]	5-47	96.1	0.252	6	204.4**

Note: CI-Confidence Interval, PI-Prediction Interval, CE- Clinical Examination, NS-Not Significant, *- Significant ($P<0.05$), **- Highly significant ($P<0.01$).

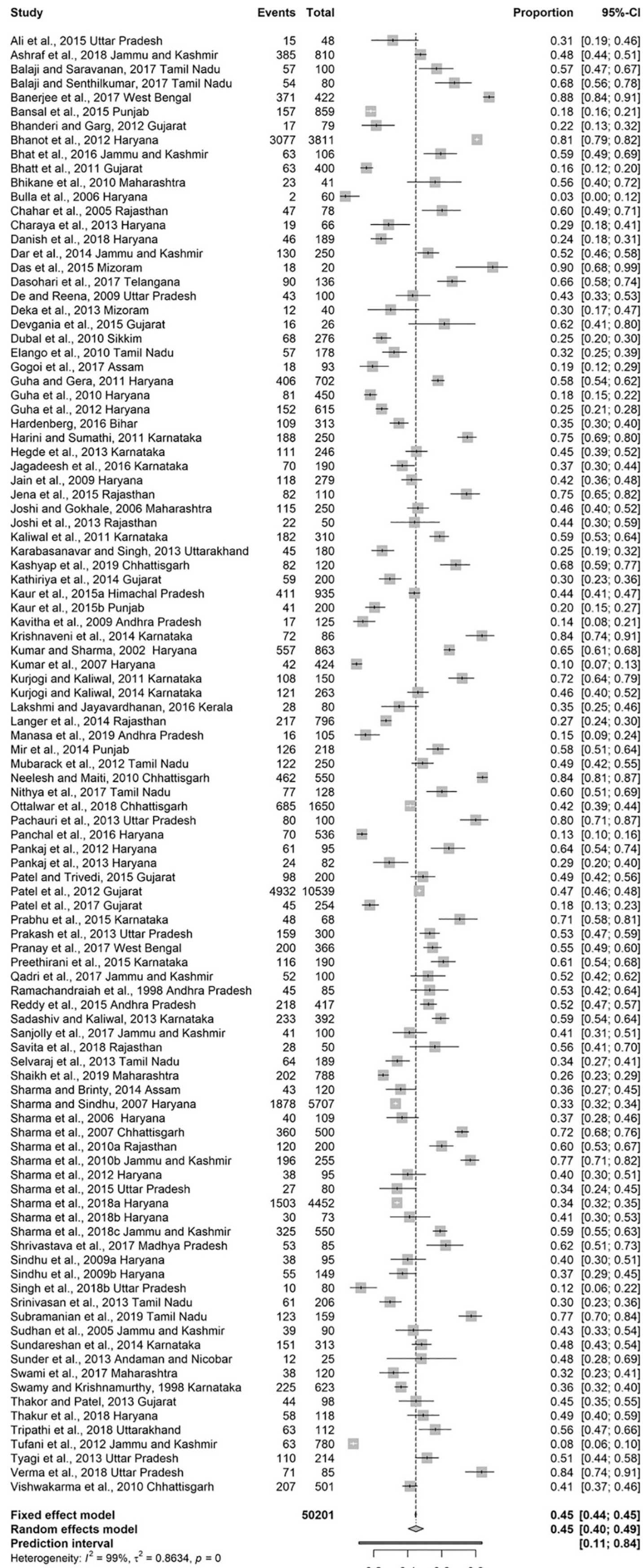

Fig. 5. Forest plot showing the Subclinical mastitis studies from India and their prevalence estimates.

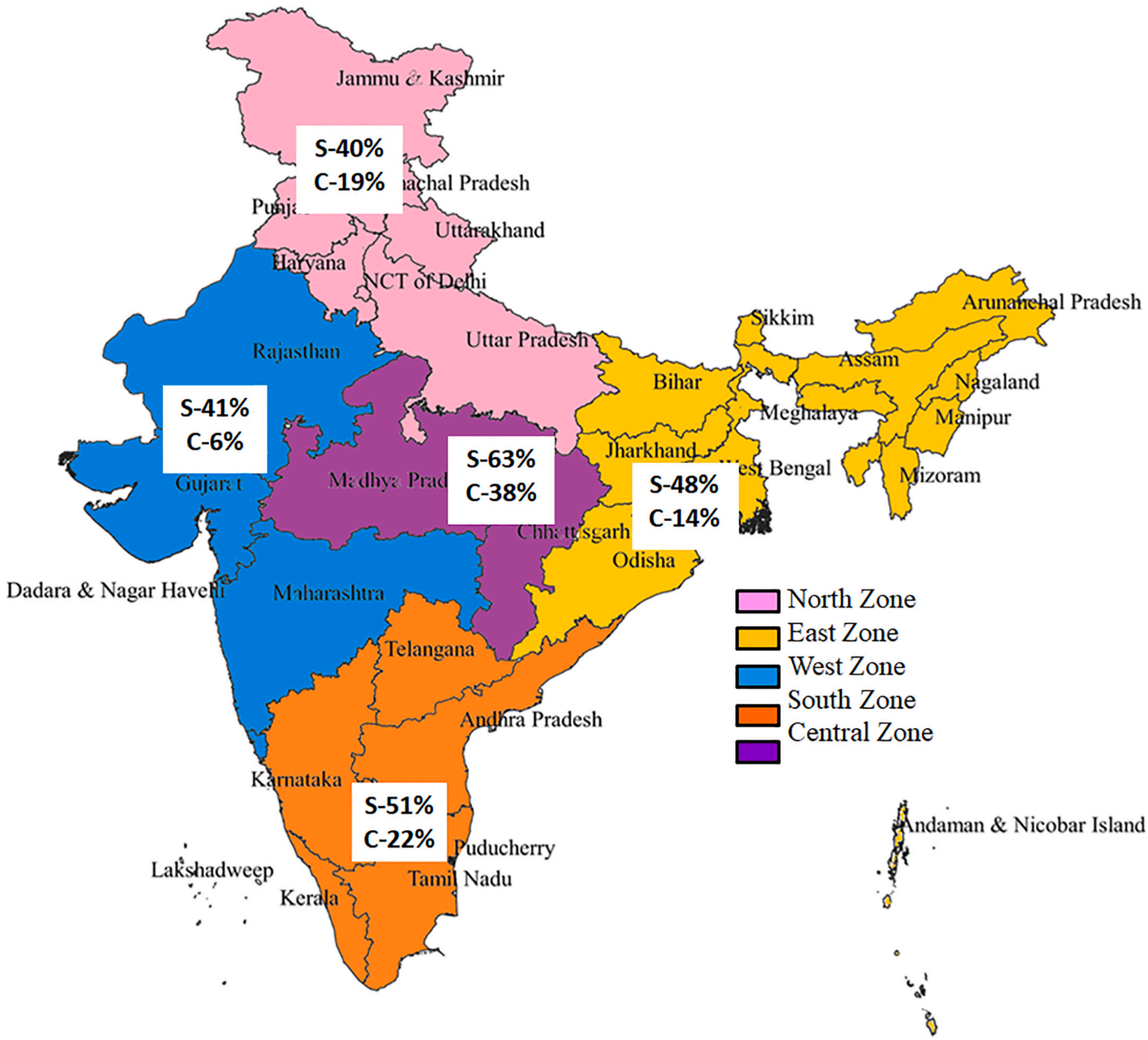

Fig. 6. India map showing the zone-wise prevalence of Subclinical (S) and Clinical (C) mastitis.

more mastitis cases and also more cattle and buffalo population in these zones. Zone-wise determination indicated the high prevalence in the Central zone which includes Chhattisgarh and Madhya Pradesh states. As suggested, the place where the dairy cows were kept, was not suitable for milking, and also the milkman not following the proper methods of clean milk production (Kashyap et al., 2019). Might also due to fact that the manual milking methods in unorganized farms were a major predisposing factor for increased mastitis prevalence (Ottalwar et al., 2018) in these states in the Central zone. The cattle showed high SCM prevalence compared to buffaloes, which confirms the assumption that the buffaloes are less susceptible to mastitis because of tight sphincter muscles around the streak canal in the teat. In India, mostly the SCM was diagnosed by using CMT, and rarely SCC and bacterial culture examination were followed, and hence the more number of studies encompassed for meta-analysis have used CMT than other methods. Iraguha et al. (2015) stated that the CMT was the most desirable screening test for SCM in field situations and comparable highly to other diagnostic tests. But the SCC and bacterial culture examination are the more sensitive methods for SCM diagnosis from milk containing major mastitis pathogens. Furthermore, the positive CMT reaction depends on the concentration of somatic cells in the milk (Sharma et al., 2018b). The pooled prevalence estimate of CM in India was 18% in this study and

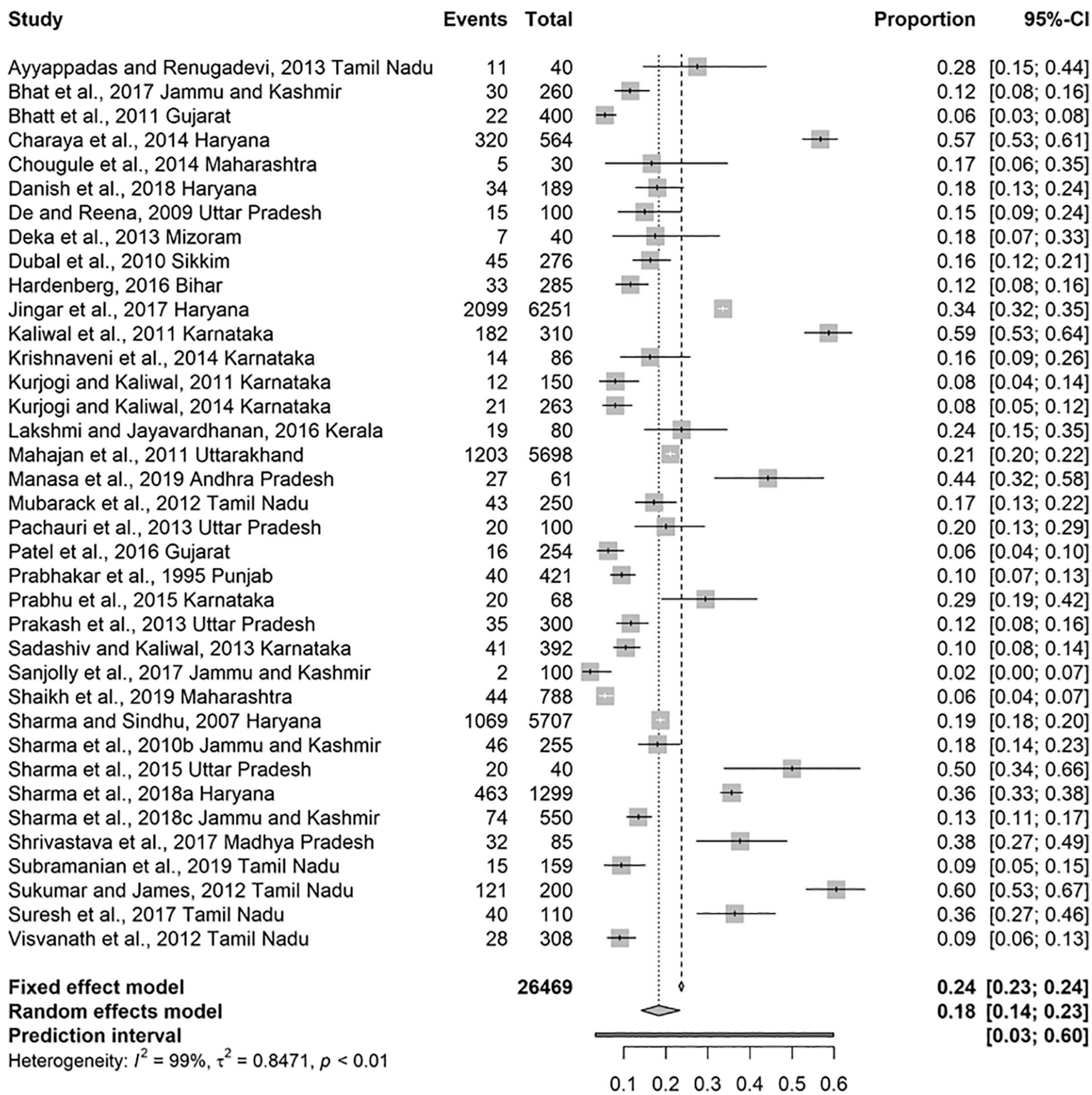

Fig. 7. Forest plot showing the Clinical mastitis studies from India and their prevalence estimates.

concurred with the previous study which reported as 16.08% (Bangar et al., 2016). However, another study reported a CM prevalence of 27% based on a meta-analysis (Krishnamoorthy et al., 2017) and was high in comparison to this study. This could be attributed to the variation in the study period duration considered for meta-analysis which was more in the present study than the previous study. Furthermore, this might be due to the increasing trend in the CM prevalence during 2011-19 of late due to enhanced awareness on the milk quality and mastitis among the dairy farmers. High CM prevalence was observed in the Central zone as that of the SCM and the reasons attributed may be the same as discussed earlier. The variation in the prevalence of mastitis amongst studies may be partly due to diagnostic tests used, sampling strategies followed, and criteria for mastitis and the risk factors encompassing the stage of lactation, parity number, cattle, and buffalo breeds comprised in the studies (Shrivastava et al., 2017). There was no difference in CM prevalence estimates attained based on species-wise (cattle and buffaloes) and method-wise (CE and other methods) was observed. The clinical examination was the predominantly adopted method in reporting CM prevalence by the majority of the studies in both the World and India. Based on the findings from this study, the high-risk zone for the SCM and CM was the central zone and the states with high prevalence were known. This will be helpful for the policymakers and various stakeholders in implementing preventive measures for mastitis. Further, there is an urgent need for the farmers to adopt the dairy management using

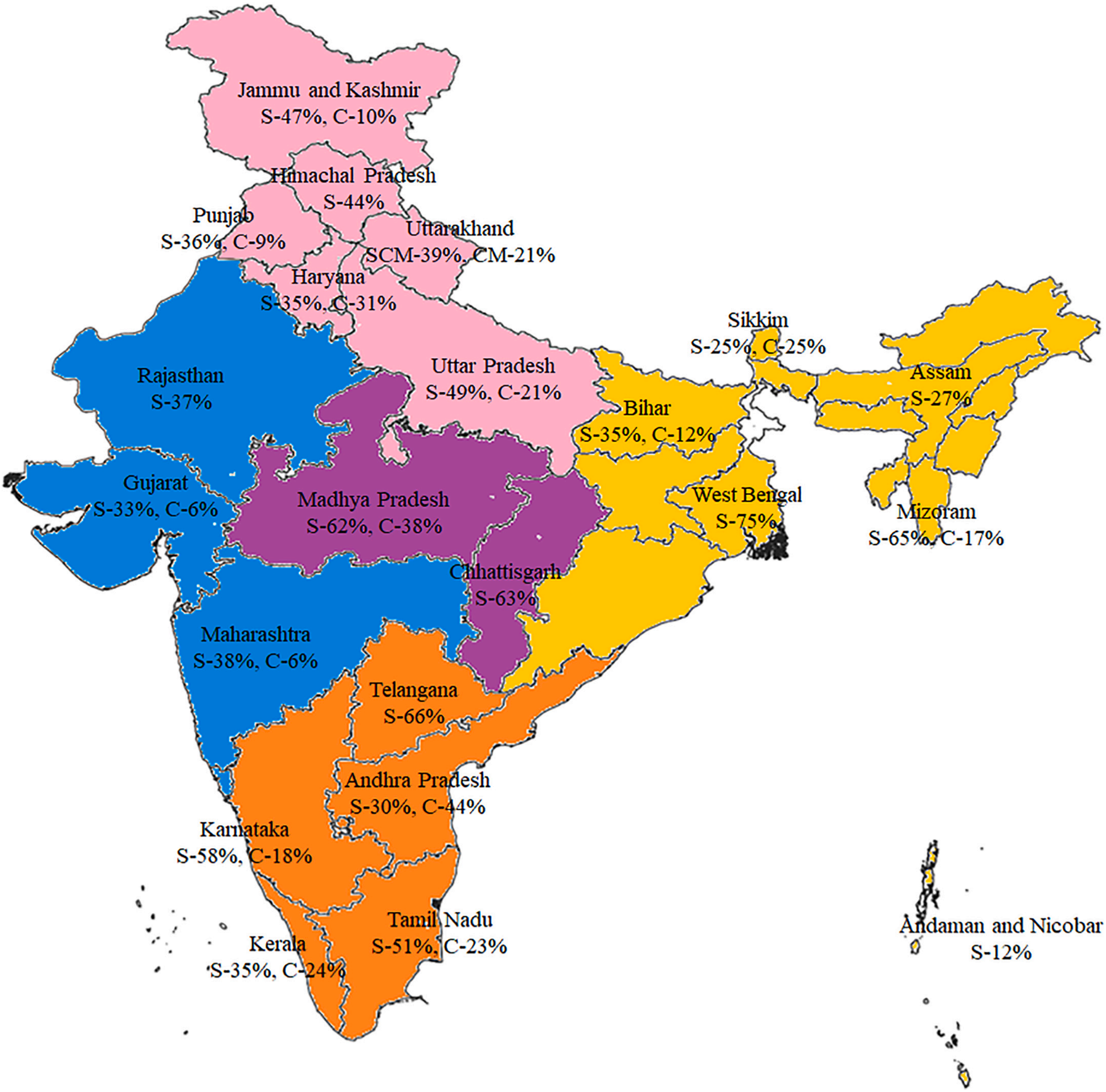

Fig. 8. India map showing the state-wise prevalence of subclinical (S) and clinical (C) mastitis.

scientific approaches by embracing dairy extension methods with mastitis awareness focus, practices of clean milk production, regular screening for mastitis, dry cow therapy, and culling of animals with chronic mastitis from the dairy farms.

In this study, there are limitations or constraints in the prevalence estimates obtained by using meta-analysis, as it might not provide the estimate for the association of SCM and CM prevalence with various risk factors in the studies reported. Further, several factors that might lead to variation between the studies are a breed of the cattle and buffaloes, the genetic makeup of the dairy animals, lactation number, stage of lactation, potential milk yield, dairy managemental practices, weather conditions, geographical area, spatial and temporal disparities in studies reported from various countries of the World. To compare the results between diverse studies, the common diagnostic test for SCM and CM prevalence were considered as diagnostic criteria and most studies included CMT for SCM and CE for CM diagnosis. Furthermore, this study forms the first report of SCM and CM prevalence in the World and its various countries by meta-analysis method except for India. Thus, the literatures collected will form a database on SCM and CM prevalence studies at one place for easy access to researchers working on mastitis in the future.

5. Conclusion

In conclusion, the present study estimated the pooled prevalence of SCM and CM in the World for the first time by using a meta-analysis method. A high prevalence of SCM than CM was observed in the World, indicated the importance of SCM. It also advocates the need for scientific dairy management methods to be adopted in various countries to reduce the SCM and CM prevalence in the World. The continent-wise and countrywide SCM and CM prevalence estimates will help the various stakeholders concerned with dairying, in developing the infection prevention and control strategies to be followed in dairy farms. In India, the detailed analysis and prevalence estimates will help the various zones and states to take up the mastitis prevention and control methods, based on the severity, and also helps in the clean milk production. The prevalence estimates will help the policymakers and stakeholders to make an informed decision on prevention strategies for mastitis by using scarce resources. Furthermore, the current study provided the metadata on mastitis prevalence studies from 61 countries of the World in this report and will be very useful for the researchers and various stakeholders. However, there is a need for more studies on mastitis prevalence from other countries in the World that are not included in this study, for obtaining more accurate prevalence estimates. To reduce the occurrence of mastitis in the World, there should be a timely diagnosis and therapeutic interventions by field Veterinarians and scientific management of dairy farms both in organized and unorganized sectors, to improve milk production and feed the world population. Furthermore, mastitis is present for a long period of more than 100 years in dairy animals and suitable vaccination or newer strategies may be implemented based on the causative organisms prevalent in particular geographical areas in the World.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rvsc.2021.04.021.

Declaration of Competing Interest

The authors declare no conflict of interest.

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