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Is Ganga the longest river in the Ganga Basin, India?

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The length of the main trunk in a river basin is an important morphometric parameter and it depends on the size of the drainage basin. The Ganga River Basin is one of the largest basins in the world with the Ganga River considered to be the main stem. Variable lengths of this river in the literature motivated us to study its exact length and also to test whether geomorphically it is the longest river in the basin. The results show that the maximum river length of 2758 km is attained when source is considered at the headstream of the Tons River. This length is more than any of the traditional lengths of the Ganga River in the literature. We propose to call the longest segment of the river in Ganga Basin as the Himalayan Foreland River.

Keywords: Ganga Basin, drainage network, headwater, river length, source stream.

LARGE river systems have complex drainage network relationship in the hinterland. The Ganga River is one such system that includes several tributaries originating in the Himalaya, viz. Bhagirathi, Alaknanda, Yamuna, Ramganga, Ghaghara, Gandak and Kosi. Traditionally and culturally it is believed that the Ganga River originates from the Gangotri Glacier (Gaumukh). This point of origin has been used for the purpose of calculating the length of the river – that is often considered to be ~2600 km – based on which it is ranked 34th globally[1]. According to the United States of Geological Survey (USGS), 'a river's length may be considered to the distance from the mouth to the most distant headwater source (irrespective of stream name), or from the mouth to the headwaters of the stream commonly identified as the source stream'[2]. Therefore, exact length of a river can be determined by the position of its headwater (irrespective of whether it is perennial or ephemeral) and its embouchure (mouth)[3,4]. Farthest upstream point in a drainage network is defined as a source[5–7].

The Ganga River Basin comprises about 26.2% of the total land mass of India[8]. The Ganga River which originates in the Himalaya and flows through the Himalayan foreland is recognized as one of the main rivers in the Indian subcontinent. The name 'Ganga' is used after the Bhagirathi River joins the Alaknanda River at Devprayag. In the Ganga Basin, the axial river has more than one headwater and so it is difficult to define the source. Moreover, after the Farakka barrage, the river bifurcates into distributaries giving rise to different routes to the embouchure. This makes it difficult to extract the actual length of the Ganga River[9]. In the literature, the length of the Ganga River varies from slightly over 2500 km (refs 10 and 11) to 2650 km (ref. 8). In these studies, the source of the river is assumed to be at Gaumukh, and mouth of the river at the outfall of the Meghna River (also known as Lower Meghna) into the Bay of Bengal[8,10,11]. Parua[8] specified two different lengths for the Ganga considering different mouths of the river. According to him[8], the total length of the Ganga River from its origin at Gaumukh to its outfall to the sea via Hooghly and Meghna's course is 2645 km and 2650 km respectively.

Another important parameter of a river is its discharge and some workers believe that the stream that carries the largest volume of water should be the main stem[4]. The

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combined discharge of the Ganga–Brahmaputra–Meghna ranks third among the largest rivers of the world[1]. The mean annual discharge of the Ganga River is 16,648 m^3/sec and thus, occupies ninth position among the world's largest rivers[12]. Among the major Indian rivers, the Ganga is ranked second (after Brahmaputra) in terms of discharge and sediment load[13]. It carries one of the world's highest sediment loads, equal to nearly 1451 million metric tonnes per annum[1]. These above statistics have penetrated so much into our literature that it is now considered as the trunk river of the basin. In spite of the Ganga being the most important river culturally, its length is hardly measured with scientific rigour.

In this study we question whether the Ganga is the longest river in the Ganga Basin? It is important to answer this question in order to understand the river systems in the basin. Therefore, we study one of the most basic parameter, i.e. length of the rivers in the Ganga Basin to identify the longest river network and its source. While carrying out this study we also look into issues such as (a) actual source points (geomorphologically) of the major tributaries of the Ganga and Yamuna rivers and (b) importance of the length and its inclusion in the decision making for a river development programmes. The results help to identify the longest river in the Ganga Basin that improves its global rank.

In the present study, digital elevation model (DEM) of the shuttle radar topography mission (SRTM) with 90 m resolution was used as base data. The DEM was used to delineate the drainage network for the Ganga River Basin. The extracted drainages of the basin were quantitatively analysed using Arc Hydro Tool in order to derive the longest stream in the basin. The vertical error associated with the SRTM data is 16 m as presented in the original SRTM specification. However, absolute vertical accuracy of this data is shown to be better than the specified value[14]. Comparison of SRTM data and actual DEM determined shows that the absolute elevation error is less than 5 m in relatively flat basins and wide valleys on the plateau, whereas it is higher in mountainous areas[15]. Further, Paz *et al.*[16] showed that errors in calculation of length depends upon resolution of DEM, and the river length is underestimated or overestimated when its width is smaller or larger than the resolution of the DEM respectively. As the study area includes both the mountainous and flat terrain, the error associated with the SRTM data in the Ganga River Basin is variable in different terrains. Thus, the river length is slightly underestimated in the Himalaya and overestimated in the Indo-Gangetic Plains. However, it is believed that the error would be insignificant while measuring a large river.

The large tributaries (length ~1000 km) of the Ganga River Basin are analysed in order to calculate the longest river; but the rivers joining the Ganga after Allahabad are discarded on the basis of qualitative assessment. For assessing the length, the Ganga River is first divided into two segments based on the confluence of major tributaries (i.e. up to Devprayag, where length of the Alaknanda and the Bhagirathi rivers are compared, and up to Allahabad, where the Ganga and Yamuna are compared; Figure 1). As downstream of Allahabad length of the river remains the same, we added it to the length of the longest river segment till Allahabad.

Up to Devprayag, the study has been carried out on two adjoining catchments, i.e. Bhagirathi and Alaknanda basins (Figure 2), whereas up to Allahabad the parameters of length and discharge are taken into account for the Ganga and Yamuna rivers at their confluence (Figure 1). Moreover, the lengths of the Tons River – a tributary of the Yamuna – and the Yamuna River are compared at their junction. The lengths of the Yamuna and the Chambal rivers are also compared to ascertain the longest stream at their confluence.

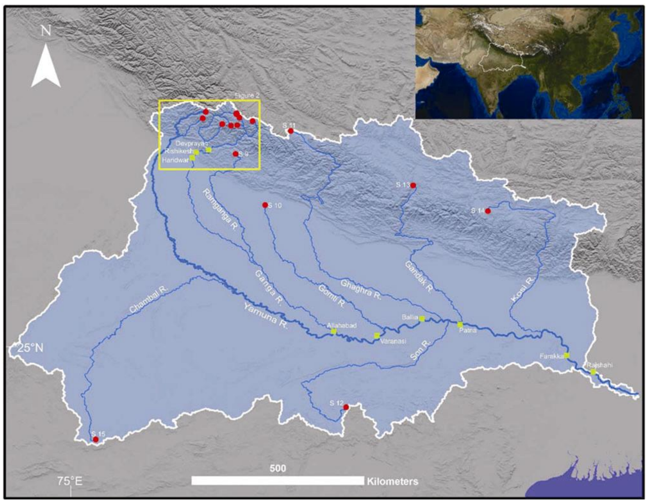

Figure 1. Map showing the Ganga River Basin and its major drainages with their source points (marked in red).

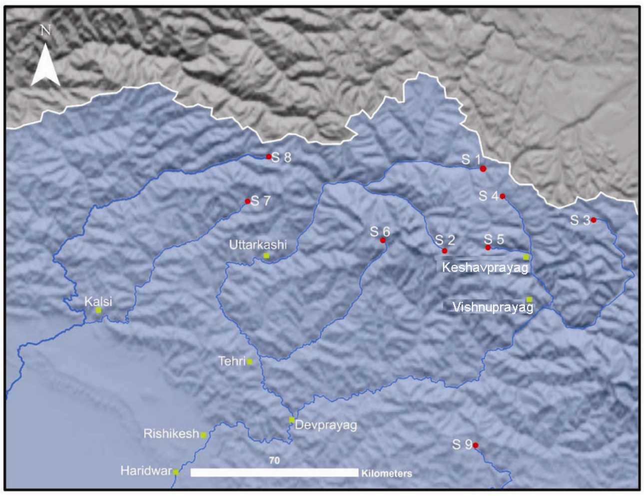

Figure 2. Map showing the source points (mark in red) of major headstreams contributing to the Ganga River drainage system and important locations.

Table 1. Comparison of the headstream tributaries of the Ganga River Basin (up to Devprayag)

River basin	Source point	Location of source point: Longitude	Location of source point: Latitude	Source elevation (m)	Length (km)
Bhagirathi River Basin	S1	79°18′53.237″E	31°5′39.789″N	4801	232
	S2	79°10′14.089″E	30°46′58.839″N	4879	230
Alaknanda River Basin	S3	79°43′42.104″E	30°54′0.433″N	4766	240
	S4	79°23′12.947″E	30°59′25.764″N	4849	210
	S5	79°19′58.355″E	30°47′45.163″N	4426	198

On the basis of the longest segment, five source points (viz. S1–S5) were selected in the headstream of the Bhagirathi and Alaknanda catchment, and distance from these source points to Devprayag was measured (Table 1 and Figure 2). In the Bhagirathi River Basin, two source points were identified at: (i) the Gangotri Glacier (S1; head of the Bhagirathi River) and (ii) head of the Jadh Ganga River (S2; Figure 2). Segment originating from S2 merges with that originating from S1 at the Bhaironghati (Figure 2). The measurements show that the Jadh Ganga River segment (i.e. S1) is longer than the Bhagirathi River segment at their confluence (Table 1). It is observed that the width of the Jadh Ganga is relatively narrow in comparison to the Bhagirathi River, which is due to the joints and fractures in the rocks.

In the adjoining Alaknanda Basin, the Satopanth and Bhagirath–Kharak glaciers are considered as the source of the Alaknanda River[17]. Three source points (viz. S3–S5) were selected in this basin (Figure 2). The Saraswati River – with its head identified as the source point S4 – flowing through the Arwa valley meets the Alaknanda River (with its head identified as the source point S5) at Mana (Keshavprayag; Figure 2); till their confluence, the Saraswati River is longer than the Alaknanda River (Table 1 and Figure 2). Further downstream, the Alaknanda River is joined by the Dhauliganga River (with source point at S3) at Vishnuprayag (Figure 2). The results show (Table 1) that the Dhauliganga River is longer than both the Alaknanda and Saraswati rivers (with their source points at S5 and S4 respectively) at Vishnuprayag (Table 1 and Figure 2).

Comparing the lengths of the segments from the selected source points up to Devprayag in these two catchments, Dhauliganga turns out to be the longest river with a length of 240 km. However, the difference between the length of the Alaknanda and Bhagirathi rivers is only 8 km. A study by Chakrapani and Saini[18] on spatial variance of the discharge in the Alaknanda and Bhagirathi basins showed that discharge of the Alaknanda River (~ 17.4 km^3 $year^{-1}$) is more than that of the Bhagirathi (~ 4.9 km^3 $year^{-1}$). Moreover, at the confluence of the Alaknanda and the Bhagirathi, it may be observed that the slope of the latter is relatively steeper than the former, indicating that the Bhagirathi is trying to adjust to the level of the Alaknanda River. So the geomorphic evidences also favour that the Alaknanda River when considered from the headwaters of the Dhauliganga makes the longest segment till Devprayag and hence geomorphically it is the trunk stream.

Comparing the results with earlier studies, we find that the length given by Parua[8] from Gangotri to Rishikesh (345 km) could not be reproduced by using any data. We used SRTM DEM, Landsat images, topographic sheets (1 : 50,000) and high-resolution *Google Earth* images to measure the length between Gangotri and Rishikesh, and the values derived were 291.5, 281, 277 and 275 km respectively. Parua[8] also calculated a length of 1760 km for the stretch from Rishikesh to Farakka, whereas in the present study a length of 1793 km is obtained for the same stretch. Though there is mismatch in the lengths of the river segments in the mountain, the downstream lengths show smaller variation (less than 2%). The fact that there is only ~5% variation in our results using different datasets in the mountainous terrain suggests that the measurement used in this study is more reliable. Further, the methodology used by Parua[8] to measure the length is not mentioned, thus making it difficult to understand the reason for variability in the length of the Ganga River in mountain.

In the Yamuna River Basin, first the lengths of the Tons and the Yamuna rivers are compared at their confluence at Kalsi (Figure 2). The Yamuna River originates from the Yamunotri Glacier[11] (marked as source point S7) and the Tons River arises near the Banderpunch Mountains[11] (marked as source point S8; Figure 2). At their junction, the Tons River turns out to be 51 km longer than the Yamuna River (Table 2). Moreover, the discharge of Tons River is twice that of the Yamuna River at Kalsi[19], thus, making Tons River the main stem.

The Chambal River (with source point as S15) – the longest tributary of the Yamuna River – originates in the Vindhyan Ranges to the south of Mhow (Figure 1) and merges with the Yamuna to the southeast of Sohan village, Etawah district, Uttar Pradesh[11] (Figure 1). At the junction of the Yamuna and Chambal rivers, the river segment (Tons River) originating from source point (S8) is around 88 km longer. The results therefore suggest that the Tons River (headstream) is the longest stream in the

Table 2. Comparison of the major tributaries in the Ganga River Basin (up to Allahabad)

River basin	Source point	Location of source point: Longitude	Location of source point: Latitude	Source elevation (m)	Length (km)
Alaknanda River Basin	S3	79°43′42.104″E	30°54′0.433″N	4766	1181
Yamuna River Basin	S15	75°38′41.84″E	22°37′1.232″N	558	1463
	S7	78°25′59.019″E	30°58′13.525″N	2447	1500
	S8	78°30′45.193″E	31°8′24.091″N	4085	1551
Ramganga River Basin	S9	79°18′7.795″E	30°4′11.928″N	1491	957

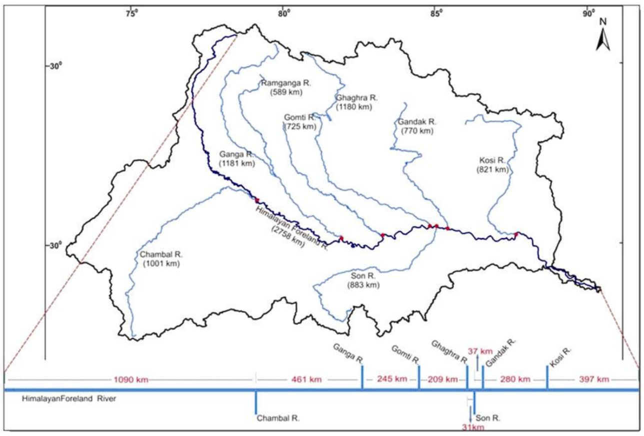

Figure 3. Lengths of major tributaries (in brackets) of the Ganga River and line diagram depicting the distance between adjacent confluences.

Yamuna basin and its length up to Allahabad is 1551 km (Table 2 and Figure 3).

When compared at Allahabad, the longest segment in the Yamuna Basin (with its source point at the head of the Tons River, i.e. S8) measures 370 km longer than the longest segment of the Ganga River (i.e. from S3; Table 3). Moreover, the discharge of the Yamuna (93,020 MCM) at the confluence is also more than that of the Ganga River (58,980 MCM)[19].

The significance of a river depends upon its discharge, sediment yield and length[20]. The length of a river plays a significant role while studying transfer of signals of an extreme event, e.g. how rapidly the signal of an intense rainfall in the source of a river could travel to the sink would depend upon the length of the river; similarly, length of a river can also control to some extent how far the signal of a sea-level fall will migrate upstream.

The length and discharge data together suggest that there exists a river within the Ganga Basin which is longer than the Ganga River by at least 370 km (Table 3). This is the segment originating from the Banderpunch Mountains (i.e. Tons River). But, is this the main stem in the Ganga basin? It is well known that the main stem of a river sets the base level for its tributaries. Therefore, we measured incision by both the Ganga and the Yamuna rivers upstream of Allahabad up to 100 km. The results showed that the Yamuna River is more incised, thus setting the base level for the Ganga River (Figure 4). This analysis further strengthens the result of the present study that the river segment in the Ganga Basin from the Banderpunch Mountains (source point S8) is the main stem. The total length of the river comes to 2758 km up to its confluence with the Brahmaputra. This length improves the overall rank of the trunk river of the Ganga Basin and places it in the 31st position[21]. We propose to call this longest segment of the river as the Himalayan Foreland River (HFR) for scientific studies (Figure 3). So, this stream becomes the axial or trunk river in the Ganga River Basin. It is noteworthy that the total length of the river increases even further (3006 km) when the length of its minor distributary – the Hooghly River – is taken into account. However, the main segment which is called as Padma River after entering Bangladesh, is considered in this study as the distal main segment of the longest river.

This finding has huge implications on the geomorphic study of the Ganga Basin rivers. It would mean that the HFR sets the base level for the Ganga River. Since several relationships are worked out with the length of a river (e.g. basin area versus stream length, discharge versus stream length, grain size versus stream length, etc.), there is a need to re-evaluate these relationships for the Ganga Basin with this length. Further, changes in these relationships can affect the predictability of river response that can in turn influence any river-related planning in the Ganga Basin.

Another important outcome of this study is that the Ganga and the Ghaghara rivers become two important tributaries of the HFR (Figure 3), which are comparable in length (~1180 km). Therefore, now these two rivers can be compared and also studied for their influence on the HFR. The results also raise an important question; in spite of greater length why has this segment not gained importance? This question remains unanswered and the only possible answer could be that rivers in the Ganga Basin attained their present set-up at a much later stage, e.g. the Yamuna River is suggested to have started flowing towards east only during Late Pleistocene[22].

The present study on the length of the rivers in the Ganga Basin demonstrates that geomorphically the Ganga River is longest when source point is taken at the head of the Dhauliganga River. Also, the Yamuna River is longest when the source point is considered at the head of its

Table 3. Summarized results of the present study and comparison of two major streams in the Ganga River Basin (up to Ganga–Brahmaputra River junction)

River basin	Source point	Location of source point: Longitude	Latitude	Source elevation (m)	Length (km)
Alaknanda River Basin	S3	79°43′42.104″E	30°54′0.433″N	4766	2388
Yamuna River Basin	S8	78°30′45.193″E	31°8′24.091″N	4085	2758

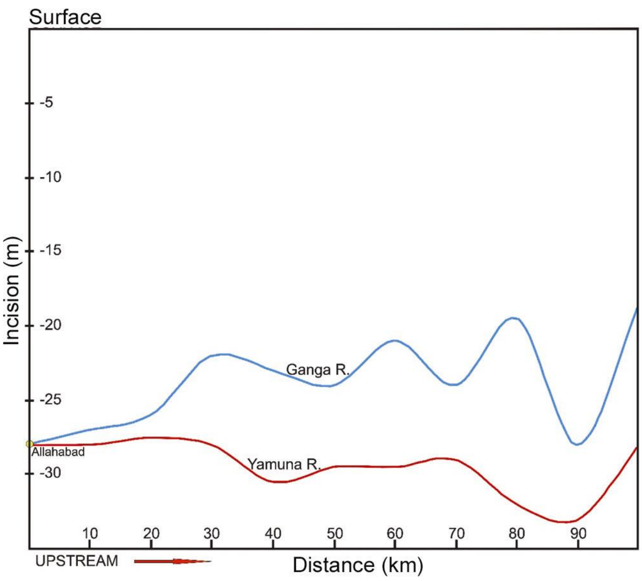

Figure 4. Graph showing the incision for the Ganga and Yamuna rivers from Allahabad to upstream in the respective valleys for a stretch of 100 km.

tributary – the Tons River. Most importantly, this study demonstrates that the Ganga is not the longest river in the Ganga Basin. The longest river segment is when the source point of the Tons River is considered and measured up to the confluence with the Brahmaputra River. It yields a length of 2758 km, which elevates the global ranking of the Ganga River to 31st position. It is suggested that longest river of the Ganga Basin be called the HFR. This finding raises the need to evaluate the responses of the rivers considering HFR as the trunk stream.

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