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THE INDIAN MONSOON – PHYSICAL AND HUMAN GEOGRAPHY

The monsoon is a seasonal wind system operating over southern Asia, primarily over the Indian subcontinent. In the wet season, winds blow from sea to land, bringing the main annual rainfall to most of India, Bangladesh, Pakistan and Burma. Some areas remain dry, such as the Thar Desert in Pakistan. Offshore winds in the dry season mean these regions have little rain.

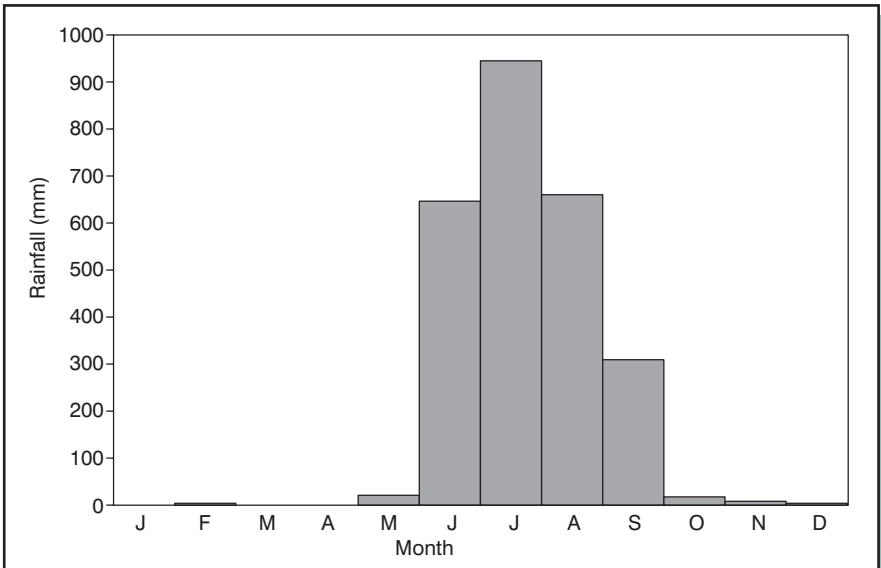
The monsoon climate is characterised by a very strong seasonal contrasts. Generally three seasons are identified:

1. Rainy season, June–September. The rains are brought by the south-west monsoon in June. The late arrival of the monsoon is potentially serious for poor rural dwellers. The rains are especially intense on higher ground – where the Western Ghats face the Arabian Sea, for example, and even more on the uplands at the head of the Bay of Bengal.
2. Cold dry season, October–January. The "winter" conditions are dominated by the north-east monsoon and temperatures are lower.
3. Hot dry season, February–May. This season ("summer") occurs all over India. In the interior, especially the north, temperatures are very high. This season is not entirely rainless, as there are convectional thunderstorms in places and tropical cyclones affect the Bay of Bengal coast.

Figure 1: Bombay (Mumbai) and Delhi: Average monthly rainfall and average daily maximum temperature.

	Bombay		Delhi	
	Rainfall (mm)	Maximum Temperature (°C)	Rainfall (mm)	Maximum Temperature (°C)
January	0	31	25	21
February	1	32	22	24
March	0	33	17	30
April	0	33	7	36
May	20	33	8	41
June	647	32	65	40
July	945	30	211	35
August	660	29	173	34
September	309	30	150	34
October	17	32	31	35
November	7	33	1	29
December	1	32	5	23

Figure 2: Bombay: Average monthly rainfall.



Causes of the monsoon climate of India

India is a tropical and sub-tropical country protected from the north by the Himalayan mountain range. Hence we can say that the climate of India is influenced by:

1. its location partly in the tropics and partly just outside
2. the nature of the global wind systems over the country
3. the barrier to movement of air masses between South Asia and the continental interior caused by the Himalayan mountains
4. high-level air movements.

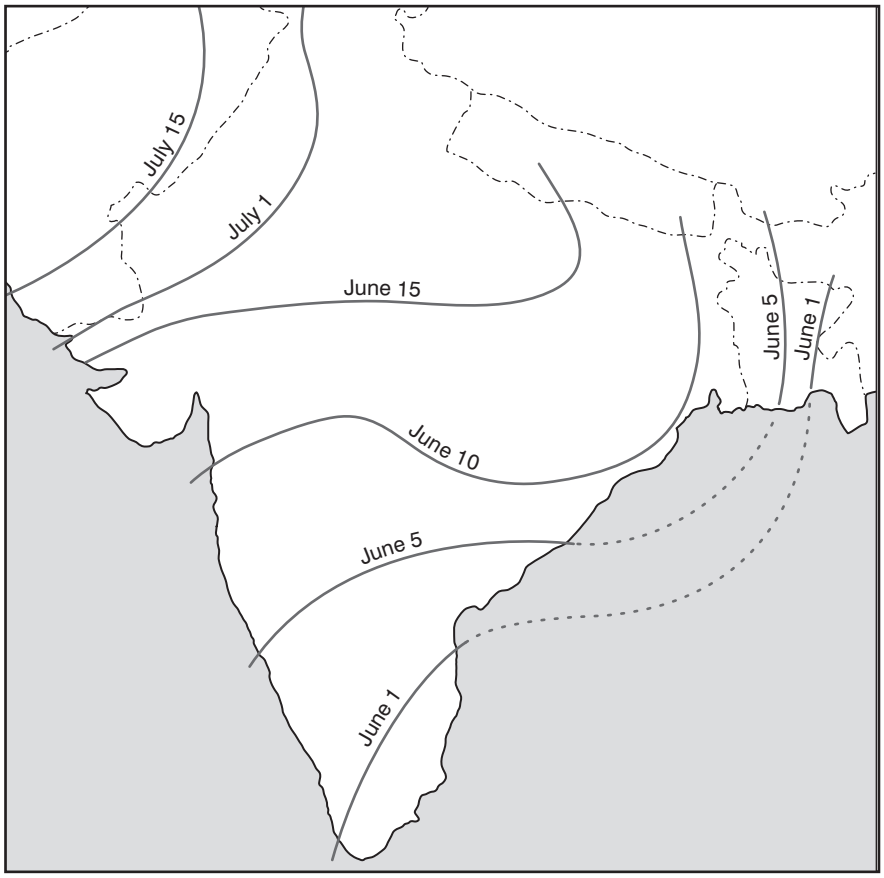
There are two traditional explanations of the causes of the monsoon. A third was added in the second half of the 20th century as understanding of wind in the upper atmosphere/troposphere increased. These explanations are not mutually exclusive.

1. Differential heating – land and sea breezes on a large scale

Land and sea breezes occur over the course of a day as a result of the differential rates of warming of the land and the sea. Towards the end of the day the warmed air over the land rises and cooler air from the sea moves underneath the rising air. Conversely, towards the end of the night, the air over the sea is warmer and is displaced by cooler air from over land. In South Asia this process is repeated on a much larger scale and over a longer time frame. During the winter, the air over the sub-continental interior, the Indo-Gangetic plain, just south of the Himalayas, cools more rapidly than the air over the Indian Ocean. The air is dense and flows outwards like a land breeze. In the summer the warm, low density, air mass in the interior rises and is replaced by inflowing sea breezes.

This explanation sees the monsoon as a thermally driven convection system,

Figure 3: Average date of onset of the rainy season



with winds flowing from high to low pressure areas. However, the simple expected northerly (summer) and southerly (winter) wind directions are complicated by the earth's rotation and the resulting Coriolis force. The Coriolis force pushes the wind direction from north to north-east and from south to south-west, as a consequence of the Earth's spin.

2. Seasonal movement of planetary wind belts.
The Earth's atmosphere is marked by a series of wind belts which move north and south as the sun moves throughout the year. The Inter-Tropical Convergence Zone more or less follows the sun north and south of the Equator, although by less than the sun moves. Typically, the ITCZ moves to 10°N in July and 5°S in January – the asymmetry is associated with the greater area of land in the Northern Hemisphere than in the Southern Hemisphere. However, over India and the Indian Ocean the large expanse of ocean to the south magnifies the contrast and the ITCZ moves as far north as 25°N, i.e. across the north of the Indian peninsula.

3. Circulation in the upper troposphere
The troposphere, the lowest layer of the atmosphere extends well above the Earth's surface and includes opposing air movements which complement the surface winds. During the cold season low pressure in the upper troposphere gives rise to high level westerly winds (i.e. more or less crossing the path of the surface winds). The westerly air stream is split in two by the Himalayas and Tibetan Plateau. The southern of these two arms has at its heart a vigorous jet stream and this supplements the air movements originating in the lower troposphere. By late May and early June these upper air flows have been reduced in vigour and the jet stream passing south of the Himalayas has become intermittent. The warming of the Tibetan Plateau in the summer gives rise to strong easterly winds in the upper troposphere. These upper air flows facilitate the rising of air masses at high altitudes and help provide the full force to the lower troposphere south-west monsoon. The start of the easterly jetstream is crucial in the process and signals the start of the south-west monsoon. By late September to early October the easterly jetstream weakens and moves south, weak upper westerlies are re-established over North India and the monsoon begins to retreat.

Nature and origin of the rainfall

The Indian monsoon is marked by extremely high rainfall levels (Figure 6). The immediate causes of the rainfall are (1) convectional cooling caused by the air mass rising at uplands or within thunderstorms, and (2) cyclones, varying from depressions of the type which bring precipitation to the UK, to hurricanes. In either case the rainfall is intense.

The winds of the south-west monsoon are forced to rise at mountain ranges, notably the Western Ghats, and the Khasi and Jaintia Hills, but the Himalayan Range is sufficiently high to divert the winds. The weather station at Cherripunji in the Khasi Hills holds the record for annual rainfall (2455mm in 1974) and daily

Figure 4: Delhi: Average daily maximum temperature

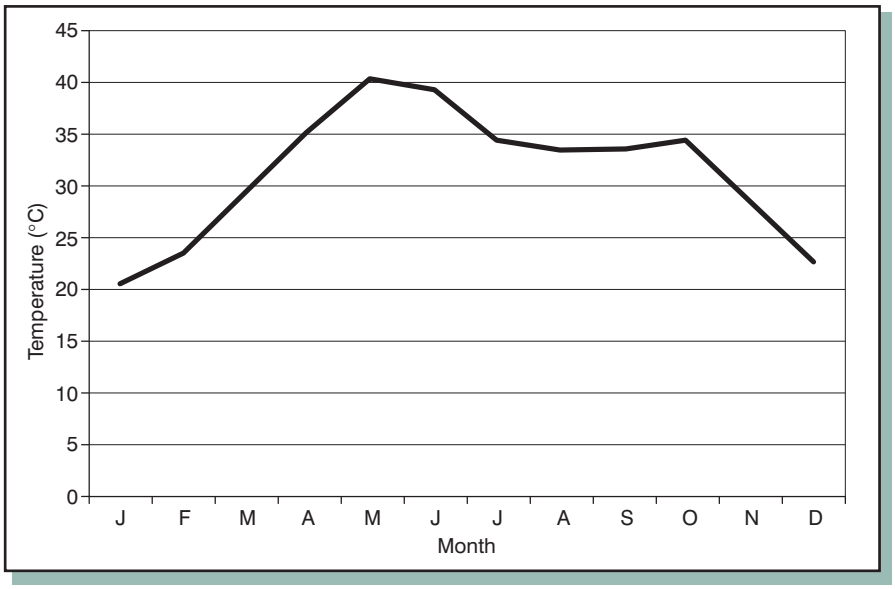


Figure 5: Monsoon rainfall as a percentage of annual rainfall

rainfall (1563m on 16 June 1995). Deep depressions form in the Bay of Bengal during the south-west monsoon. They carry water vapour on land into North India. The strength of the weather systems facilitates the formation of vigorous depressions which are diverted from their northward path by the Himalayas and so proceed along the Ganges, losing strength as they proceed inland. Yet more vigorous weather systems develop into hurricanes which inflict considerable damage on the Bay of Bengal coast.

The Monsoon and human activity

The strongly seasonal climate has an impact on human activity. Settlements are designed to cope with both the long dry season and the intense rain. Houses have wide overhanging eves – useful to protect against both sun and rain – and streets have deep and wide drains. The monsoon also has an impact on the health of the population and agriculture.

Agriculture

As an example of the dual impact of the Green Revolution and the monsoon we can note that the production of rice shows a long term increasing trend, but also fluctuates year to year according to the strength of the monsoon. Figure 7 shows rice production and average rainfall in India for the years 1990 to 2000. (O'Hare, 1997, p 219, provides a longer series, 1964 to 1994.) The increasing trend in rice production is apparent, but so too is the variation related to the monsoon rains.

There is a clear seasonal pattern in agriculture and the rural scene. As an example we will look at the Ganges plain in northern India. This is a naturally fertile area, built on alluvial deposits, which has high potential for agriculture and produces a high proportion of India's food grains (mainly rice and wheat) and cash crops like sugarcane. In this region the nature of agriculture is undoubtedly shaped by the climate. But conditions vary along the 700 mile length of the plain from Bangladesh to Delhi. Elements of the traditional agricultural activities remain – but there has been a marked extension of the area irrigated and this, together with the other changes which are included under the umbrella heading "Green Revolution", has had a strong positive impact on agricultural output.

The state of Uttar Pradesh has rainfall averaging 750–1000mm. This is the section of the Ganges plain most distant from the Bay of Bengal.

The present cropping pattern is characterised by three crop seasons: (1) *kharif* (July to mid-November) (2) *rabi* (mid-November to March) and (3) *zayad* (April to June). The cropping routine is still similar to that which has existed for centuries but the security of production, especially of the dry season crops, has improved. The dominant kharif crop is paddy rice, others include millets and maize. The kharif crops require least in terms of inputs – irrigation is not necessary during the rains and only fertilisers and insecticides are used on rice. Wheat dominates the dry rabi season just as rice does the kharif crops. However, in contrast to rice, this cereal needs substantial amounts of irrigation water, and generous applications of fertilisers and insecticides. Other rabi crops are barley and gram. Most of the agricultural land is cropped twice but very little – perhaps only one twentieth – is cropped a third time, during the hottest and driest part of the year. Typical zayad crops are maize and vegetable crops. Uttar Pradesh is the second largest producer of rice and the largest producer of all food grains in India. It also is by far the largest producer of sugarcane.

Further to the east, closer to the Ganges delta in Bangladesh, even 50 years ago there was much more irrigation and hence a three-crop agricultural year. The average rainfall in West Bengal is 1500–2500mm. There is more water available for irrigation. Being closer to the Bay of Bengal the monsoon breaks about a

week earlier in West Bengal than Uttar Pradesh while at the end of the season the lower courses of the rivers have a strong enough flow to permit more irrigation. Here much more paddy rice and much less wheat is grown.

Health

Two types of disease peak during the rainy season. They are diseases spread by mosquitoes and water borne infections. Mosquitoes breed in the ephemeral water bodies created by the rains and malaria and dengue fever cases increase.

Typhoid is rare during the dry seasons but increases during the monsoon as foul drains and tanks overflow into fresh water. The same is true for a number of other gastrointestinal infections.

References

O'Hare, G. (1997) "The Indian Monsoon Part 1: The Wind System" and "The Indian Monsoon Part 2: The Rains" *Geography* 82 (3 and 4) 218–230 and 335–352.
Spate, O.H.K and Learmonth, A.T.A. (1957) *India and Pakistan* (3rd edn, Methuen).

Figure 6: Average annual rainfall

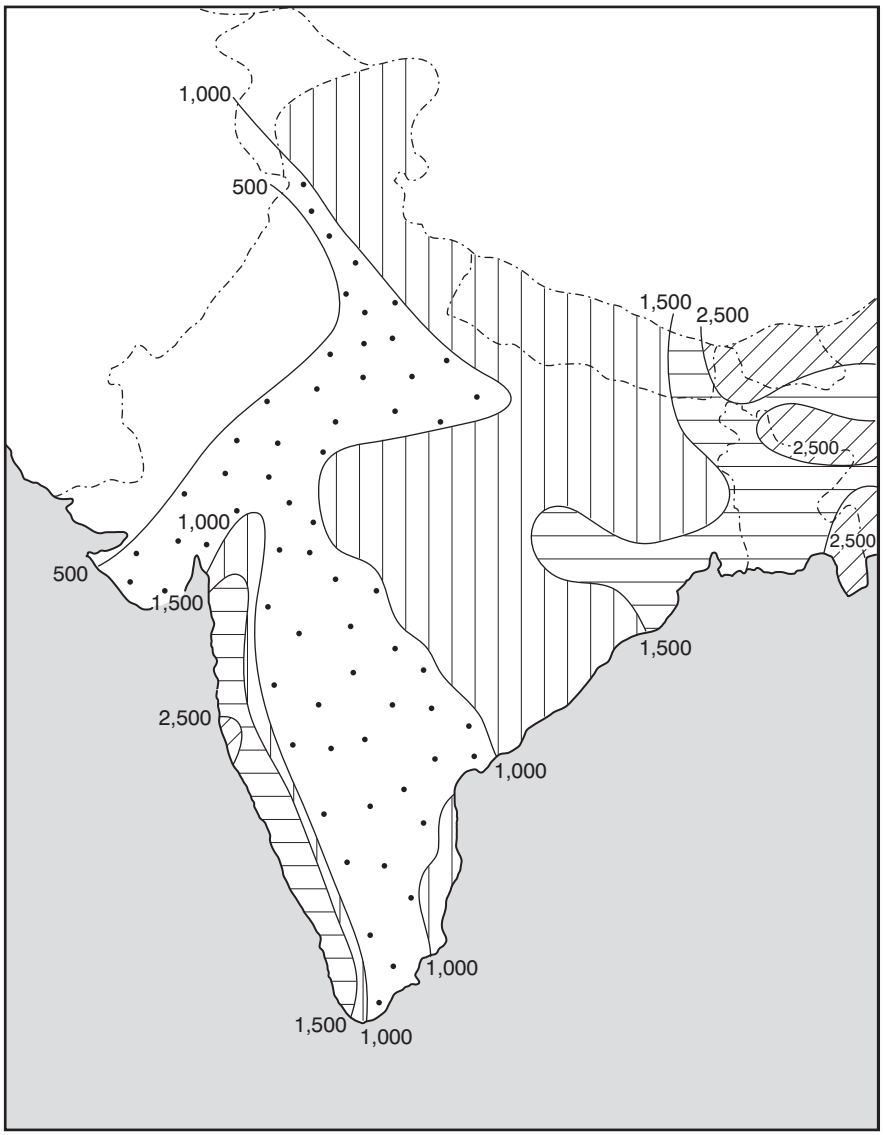
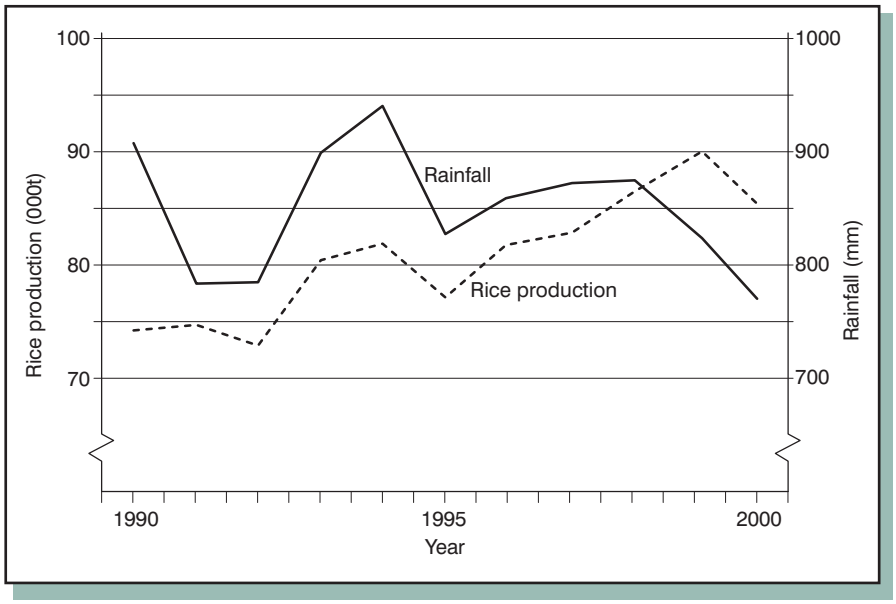


Figure 7: Rainfall and rice production, 1990-2000



FOCUS QUESTIONS

1. Assess the importance of planetary influences like global wind systems and regional influences like relief in the operation of the Indian monsoon.

2. "Almost every aspect of life in the Indian sub-continent is affected or even dominated by the monsoon" (Spate and Learmonth, 1957). Discuss this statement with reference to (a) rural and (b) urban India.