An indirect method for forecasting the annual food production of India

The green revolution which increased the annual food production of India drastically was made possible by the application of science and technology to agriculture. The annual food production of India depends on the type of seeds used, the annual rainfall over the country, especially during the south-west (SW) monsoon season, the crop area, availability of irrigation facilities, fertilizers, pesticides and also on the government incentives to the farming sector during a year. The total technological inputs to the farming sector has been growing steadily and is difficult to quantify. Therefore, to simplify the forecasting models of food production in India, the total technological inputs to the agricultural sector is assumed to increase by unit amount every year.

The growth and fluctuations of annual food production (consisting of rice, wheat, coarse grains, and also grams and pulses) have been examined recently by Gadgil et al. Parthasarathy et al.2 had earlier obtained a correlation coefficient of 0.61 between the rice production anomaly of India and the Indian SW monsoon rainfall. Chowdhury and Das3 made a multiple regression model for forecasting the kharif food production of India, using Indian SW monsoon rainfall as one of the parameters of the model.

Two indirect but slightly different models to forecast the annual food production of India are presented in this note. Both the models use yearly variations in SW monsoon rainfall in different forms as one of the parameters.

Data on annual food production of India and average crop area of subdivisions were obtained from reports of Indian Agricultural Ministry or other Government of India publications such as India, 1998. Data on SW monsoon rainfall are from reports of India Meteorological Department such as Mausam. The all India rainfall anomaly values are computed from the sub-divisional rainfall data following the method of Mooley and Parthasarathy. For the computation of rainfall index used in the second model, the average crop area of the sub-divisions is considered. The computation is based on the monthly rainfall data. The rainfall index is a measure of the percentage area which receives excess or deficit 10 to 25% rainfall, after equating the nearly equal plus or minus rainfall percentage areas. The mean of the four monthly values is taken as the seasonal index. Since the index values during the period show a rising trend during 1989 to 1998, the values have been standardized by subtracting the mean value from the yearly values.

The annual Indian food production has been growing at a linear rate since 1980. This increase in food production is due to the increased use of technology in agriculture, assumed to increase linearly since 1980. As has been explained by Chowdhury and Das, a dummy variable, $X_1$, has been chosen for representing the increasing technological input to agriculture by unit amount every year. They have also noticed a significant rise (fall) in the kharif food production of India in good (bad) SW monsoon rainfall years. Since most of the annual rainfall over India occurs during the SW monsoon season, the SW monsoon rainfall anomaly has been included as another parameter in the forecast model.

In the first model, the data for 16 years from 1982 are considered. The food production is assumed to increase every year because of technological advances which are represented by one of the parameters ($X_1$). The fluctuations in yearly food production from the mean line in different years are attributed to the variation in seasonal SW monsoon rainfall anomaly ($X_4$). A multiple regression equation of the form $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_4$ makes the model. Here $\beta_1$, $\beta_2$, $\beta_4$ are constants and $X_1$ is the serial number of the years starting from 1982 = 1, 1983 = 2, etc., $X_2$ is the seasonal SW monsoon rainfall anomaly, and $Y$ is the annual food production of India. The actual equation fitted to the 16 years of data is

$$Y = 136.89 + 3.64 X_1 + 0.684 X_4.$$

For the agricultural year 1999–2000, $X_1 = 11$ and $X_4 = -5.4$, substituting in the equation, we get

$$Y = 136.89 + 3.64 (11) + 0.684 (-5.4) = 136.89 + 39.04 - 3.66 = 172.27.$$  

The standard errors of the estimate are 3.37 million tonnes. The standard error of the estimate is 3 million tonnes corresponding to population standard error of estimates of 3.35 million tonnes.

The estimations of yearly food production by two similar models are not very different. Both results are below 200 million tonnes.

There are a number of limitations to the models. The models are indirect means of the measurement of food production. They do not take into account the likely variation in the north-east monsoon rainfall. The inputs into the farming methods, total area of crop land and government incentives are assumed not to vary substantially from year to year.
In spite of these limitations, the model's forecast error is about 4 million tonnes. We may use the models with caution, until better models for prediction of the annual food production are developed.


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**Palynodebris accumulation characteristics of a sediment core from the eastern part of Lower Bengal Fan**

In the investigation of the Quaternary, the botanical parameter concerns itself with the building up of the history of the flora, reconstruction and alteration in the past forest communities in response to climatic and biotic factors. In this respect the botanical parameter becomes interdependent upon the other diverse disciplines and like them it has its own technicalities and limitations. Hence palynological study coupled with sediment dynamics will give the accumulation characteristics of the palynodebris in the Lower Bengal Fan.

Marine processes play a major role in segregating pollen according to the size and morphology. Larger and more diverse assemblages occur nearest to the coast.

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**Figure 1.** Map showing location of the core sample (BC-1) collected from the Lower Bengal Fan.

**Figure 2.** Litholog of the box core-1 as observed onboard.
line and mangrove pollens are observed to increase offshore relative to other types although the absolute number of grains decrease. Although palynological investigations of ocean bottom sediments have been carried out in many parts of the world, only a few reports are available from the Bay of Bengal. Eighteen spore and pollen taxa from the Port Blair Formation (Palaeogene) of Andaman Islands were reported. The study of palaeoclimatic

**Figure 3.** Photographs showing the identified spores and pollen grains from the BC-1. a, *Tricolporites* sp.; b, *Polypodiaceaesporites* sp.; c, *Lygodiumsporites* sp.; d, *Laevegatosporites* sp.; e, *Spinozonocolpites bulbosus*; f, *Polypodiisporites* sp.; g, *Polycolpites* sp.; h, *Corrusporis* sp.; i, *Virkipollenites*; j-l, fungal spores. Magnification × 1000.
changes from the pollen analyses of site 717 core of ODP south of Sri Lanka has led to the identification of three zones as X (warm), Y (cold) and Z (Holocene-warm)\(^5\). A detailed study undertaken on gravity core collected from the sea bed, west of Narcondam Island has revealed rich assemblage of spores and pollen\(^6\). In the present study an attempt has been made to bring out an accumulation characteristic of palynodebris in the core collected from Lower Bengal Fan.

A 4-m length box core was collected at a depth of 3246 m (lat. 10\(^\circ\)43'43''N, long. 90\(^\circ\)27'44''E) during ORV 72nd Sagarkanya Cruise in Bay of Bengal (Figure 1). From the recovered core, eighty subsamples were made in 5 cm interval. Figure 2 gives the lithological observations made onboard.

Approximately 25 to 30 g of powdered samples were taken and treated with acids – 60% HCl, HF and 60% HNO\(_3\) made onboard. Figure 3 gives the lithological observations made onboard. Spores and pollen encountered are mostly pteridophytic, along with few grains of fungal spore. The following spores and pollen were identified from the core: Tricolporites sp., Polypodiaceasporites sp., Lygodiumsporites sp., Laevogatosporites sp., Spinozonocolpites bulbosus, Polycolpites sp., Polypodii-sporites sp., Corrusprio sp. and Virkipollenites (Figure 3 a–i).

Monocotyledonous angiosperm, Nypa (Figure 3 a) identified in the core, generally colonizes lagoon and river muds, where the tidal rise and fall are considerable, but the water is less saline. Occurrence of this taxa suggests prevalence of an intertidal mangrove swamp environment of the transported sediments. Re-worked pollen, Virkipollenites (Figure 3 i), an important monosaccate gymnosperm pollen characteristic of Talchir and Barakar sediments, has been identified in the core at a depth of 75–80 cm. This indicates that the river draining the Gondwana terrain of Mahanadi Basin has transported and deposited the pollen grains in the delta and which was later transported by the turbidity currents to the deep sea and deposited in the Lower Bengal Fan.

A larger number of pteridophytic spores, diverse morphological types and increased numbers of altered grains are recorded at the depth ranging between 45 and 120 cm of the core. Few fungal spores are present along with the pteridophytic spores (Figure 3 j and k), indicating that pteridophytic spores and pollen only survive such a distance of travel with high turbulence and agitation of water mass during the transportation of sediments in the Bay of Bengal. The studies on stable isotopes\(^1\) and REE geochemistry\(^5\) show higher influence of terrigenous sediments at depth interval of 45–120 cm and this zone falls in the Woodfordian (LGM) substage of Late Pleistocene\(^2\). During this period, the rate of sedimentation in the studied core is 6 cm/1000 years\(^5\). The results indicate that accumulation of pteridophytes is more in the studied core compared to that of angiosperms. This may be due to high sediment turbulence and transport by turbidity currents during Late Pleistocene. It also suggests greater atmospheric moisture and increased stream activity during the time of deposition of these sediments\(^3\).

Microsections studied from 45 to 120 cm depth intervals of the core show good preservation of woody cuticles and spores in the sediments. Petrographic studies of these sections for the percentage distribution of organic material show average content of: humic substances – fusinite and semifusinite, 35%; biodegraded terrestrial substances, 25%; structured woody material, 25%; sapropelic substances – finely divided organic matter, 10%; amorphous material, 5%.

These results indicate the presence of humic substances around 85% and sapropelic substances around 15%. Hence the sediments are land derived and deposited in humic-charcoal facies. Sharp increase in charcoal abundance in LGM (45–120 cm)\(^7\) in the studied core points to fire being a critical factor for the accumulation of such a type of palynodebris. This could be due to normal forest fire or the result of an volcanic eruption. Occurrence of forest fire in the nearby source region of the study area seems to be remote, as the conditions necessary for forest fire are not expected in a tropical and moist habitat. Since Narcondam is a volcanic island in the Andaman, it is plausible that during 18,000–20,000 BP, volcanic activity caused burning of forests, resulting in the production of pyro-fusinite which got deposited in the sediments around the island\(^7\). This factor is mainly responsible for the rich accumulation of fusinite material at 1.10–1.15 m depth of the cores studied when compared to the normal forest fire due to glacial–interglacial climatic changes.


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Reliability of urohyal bone of silver carp, *Hypophthalmichthys molitrix* (Val. 1844) for age determination

In most commercial carps, the use of scales is in vogue for age determination and calculating various growth parameters. The growth parameters are useful for the judicial management of a particular fish species. Other hard parts such as otoliths, vertebrae, cleithra, opercular bones, dentary, frontal bones, fin rays and spines are employed for age determination in fishes in which either scales are absent, e.g. members of the order Siluriformes or when scales fail to record the exact number of annual marks or the fishes have deciduous scales\(^1\)–\(^3\).

Use of the urohyal bone for age determination in *Lutjanus vittus* (Quoy and Gaimard) has been reported from Australian waters\(^4\) but there is no such report in the case of carps.

In the present communication, a successful attempt has been made to determine the age of exotic carp, *Hypophthalmichthys molitrix* (Val. 1844) using the urohyal bone, because it has been observed that the scale of this fish poses some problems in age determination, especially after the third year when the annual growth rate decreases drastically and there is overcrowding of annuli. The fishes were collected from Gobindsagar reservoir, Himachal Pradesh (lat. 31°25′N and long. 76°25′E) during August 1998 to April 2000, using gill nets of various mesh sizes to study their biology in order to pinpoint the factors for the excellent establishment of this exotic fish in a new environment.

The urohyal bone is a single median triradiate solid bone (Figure 1) with the anterior tip generally connected to the ventral hypohyals, the anterior dorsal part connected to the first basibranchial and the posterior part connected to the pectoral girdle by means of muscles. It has horizontal and vertical components, which are flat.

For the present study urohyal bones were removed from fresh specimens and muscles were separated by dipping them in water at 60–70°C for 5 min. The cleaned and dried urohyal bones were stored in ordinary envelopes with relevant data, e.g. total length, standard length, weight (in metric system). Transverse sequential sections were then cut from the anterior tip of the urohyal bone (Figure 1) using a fine jeweller’s saw. Each section was ground and polished using carborundum stone and fine ground glass. The ground and polished sections having a thickness of 0.3–0.58 mm were mounted on the glass slides in DPX and observed under transmission light using Carl Zeiss DL 5.3 VEB Documator or Getner Stereobiocular Microscope. For photography, the sections mounted on the microslides have been used as negatives (Figures 2a and b).

The urohyal bone shows circular shape in its transverse section from the anterior side (Figures 2a and b). The annual marks are very clear in the form of circular rings and are easily distinguishable. The incomplete mark at the centre of some of the sections of the urohyal bone gives an impression of the first annulus.

**Figure 1.** Lateral view of urohyal bone of *Hypophthalmichthys molitrix* (Val.1844) collected on 31 March 2000. Total length, 710 mm; standard length, 552 mm; weight 3340 g; age 4 years. Arrows indicate annual marks. Line indicates the region from where the sections have been cut. A, anterior side; P, posterior side; D, dorsal side; V, ventral side.

**Figure 2.** Transverse sections of urohyal bone of *H. molitrix* (Val.1844). a, Total length, 531 mm; standard length, 421 mm; weight, 1600 g; age 2 years, collected on 15 November 1998. b, Total length, 759 mm; standard length, 609 mm; weight, 4100 g; age, 4 years, collected on 15 October 1999. A\(_1\), A\(_2\) . . . A\(_n\); annual marks.
To find the back-calculated length it is not possible to measure the radius because distinct focus has not been marked. Hence the following method in the transverse section of the anterior part of the urohyal bone is suggested.

Draw the outline of the transverse section of the urohyal bone showing the margin and rings or marks on a tracing paper at a particular magnification, preferably at 10 × on the screen of Carl Zeiss DL 5.3 VEB Documator. Draw the straight line between two points having maximum distance and designate it as maximum transverse distance (Figure 3, $MM'$.). Measure the distance between two points on the line of the respective annuli (Figure 3, $A_1$ to $A_1$; $A_2$ to $A_2$; $A_3$ to $A_3$. . . . $A_n$ to $A_n$), and find the back-calculated lengths using the following formula.

$$L_n = \frac{A_n - A_h}{MM'} L,$$

where $L_n$ is the length of the fish when the annulus $n$ was formed; $L$ is the length of the fish at the time of capture; $A_1 - A_1$, $A_2 - A_2$. . . . $A_n - A_n$ are the distances between the respective annuli; $MM'$ is the maximum transverse distance of the urohyal bone.

While ascertaining the exact age in order to find the back-calculated length, it was found that the scale was not reliable for age determination due to crowding of annuli after the third year; therefore, the exact age could not be determined. As an alternative, transverse sections of anterior regions of the urohyal bone have been found to be more reliable. The literature shows that so far the urohyal bone has only been used in $L. vittus$ in a different way, i.e. using annual marks on the vertical (lateral) wing of the urohyal bone. The vertical wing of the urohyal bone is extremely reliable as far as age determination is concerned, but the precise measurements are not possible to calculate the back-length, hence, the final choice has fallen on the transverse sections of the anterior region of the urohyal bone.

It may be added here that annual rings present on the urohyal bone as observed in the transverse sections are more distinct, easy to count and measure, and hence most suitable to find the back-calculated length. Moreover, removal of the urohyal bone causes minimum damage to the fish.

Hence we conclude that the urohyal bone can be used for age and growth studies with high degree of precision and reliability in the silver carp, $H. molitrix$ (Val. 1844) from Gobindsagar.

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