THE ABSOLUTE MAXIMUM FOOD PRODUCTION POTENTIAL IN INDIA—AN ESTIMATE

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BASED on an understanding of the climate, soil and water resources of each region, an assessment can be made of the absolute maximum food production potential of an area in terms of grain equivalent. Such studies hlep to provide an estimate of the size of the untapped food production reservoir existing in each country. Using data from agro-climatological research and soil maps, Buringh *et al.*[1] calculated the absolute maximum food production potential of the world. After estimating the area of potential agricultural land (PAL) in different parts of the world with suitable adjustments for soil conditions and water deficiency, they onverted the climatic parameters into a single composite measure called "gross photosynthesis" (GP). They developed appropriate conversion factors to transform GP values into dry matter production and finally, into grain equivalents. Their studies indicated a maximum global production potential of 49,830 million tonnes of grain equivalents per year (Table I). According to their study, Asia has the maximum untapped production potential, followed by South America and Africa.

In recent years, the average global grain production has been of the order of 1,300 million tonnes. The postulated maximum production potential is hence about 39 times as much as the present level of production. Obviously, however, all the available land cannot be used only for grain production. A wide range of fodder, feed, fibre, fruit, timber and other plants will have to be grown to sustain the diverse human needs as well as the plant—animal—man food chain.

For making calculations of the absolute maximum production potential in terms of a mixture of crops, rather than in terms of a standard grain equivalent like wheat or rice, appropriate energy conversion data will have to be used. For example, one gram of glucose can produce about 0·83 gm starch or 0·40 gm of protein with nitrate as nitrogen source or 0·32 gm of lipids. Hence, there may be a caloric penalty if there is an increase in protein content and a protein penalty if there is an increase in calorie yield. This factor should be kept in view while analysing the significance of the absolute maximum production potential in terms of a grain equivalent.

The following two important points emerge from the study of Buringh *et al.*[1].

1. The potential agricultural land (PAL) of the world is 3,419 million hectares, which is about 25% of the total land area of the world. A maximum of 470 million hectares of this area can be irrigated. At present 1,406 million hectares of land are cultivated, of which 201 million hectares are irrigated.

2. The estimated maximum food production potential of the Indian sub-contient is approximately 3,200 million tonnes grain equivalent per year.

In India about 143 million hectares of land are at present sown every year, of which about 34 million hectares are irrigated. It has been estimated that ultimately about 77·6 million hectares can be irrigated, if all the water resources are efficiently managed. At present about 17% of the world's irrigated land occurs in India and this percentage will remain more or less the same even when the world's irrigation potential would have increased to 470 million hectares. However, as compared to the world situation, the over-all situation with regard to irrigated land is favourable in India (Table II). Of the total cultivated land 24·5% is now irrigated and it is expected that this percentage would increase to 54·3% when the water resources of the country are fully developed. In the temperate countries, however, the period of maximum and even precipitation coincides with the period of maximum solar insolation. In India, the period of maximum sunlight, namely the summer season, is however, also a period of minimum precipitation. Calculations of the potential for irrigation will undergo change when the use of desalinised water for agriculture becomes commercially viable.

We have attempted to compute the absolute maximum food production potential of India using largely the methodology of Buringh *et al.*[1], but making suitable adjustments in our calculations wherever necessary. For example, we did not consider it necessary to calculate the imaginary potential agricultural land (IPAL), since at present 46·8% of land in India is cultivated which is almost double of the IPAL for the world as computed by Buringh and Co-workers[1]. In addition to the 143 million hectare of land now cultivated every year, about 28·2 million hectares of land are suitable for cultivation. However, this land is best used for silviculture and other social forestry programmes in the villages. Therefore, we have used the actual cultivated land (ACL) as potential agricultural land (PAL). We have, however, introduced the term potential cropped area (PCA)

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TABLE I

Totals of the production potentials of continents and the world
(*After Buringh* et al. 1975)

	A	PAL	IMAP	MPDM	PIAL	IPALI	MPDMI	MPGE
S. America	1780	616·5	333·6	25224	17·9	340·7	25710	11106
Australia	860	225·6	74·2	5297	5·3	76·1	5462	2358
Africa	3030	761·2	306·5	24162	19·7	317·5	25115	10845
Asia	4390	1083·4	433·5	24966	314·1	581·6	33058	14281
N. America	2420	628·6	320·0	15443	37·1	337·5	16374	7072
Europe	1050	398·7	233·1	8289	75·9	247·1	9653	4168
Antarctica	1310	0	0	0		0	0	0
Total	14840	3714·1	1700·9	103381	470·0	1900·5	115372	49830

A	Area of a broad soil region (10^6 ha)
PAL	Potential agricultural land (10^6 ha)
IPAL	Imaginary area of PAL with potential production without irrigation (10^6 ha)
MPDM	Maximum production of dry matter without irrigation (10^6 tonnes/year)
PIAL	Potentially irrigable agricultural land (10^6 ha)
IPALI	Imaginary area of PAL with potential production, including irrigation (10^6 ha)
MPDMI	Maximum production of dry matter including irrigation (10^6 tonnes/year)
MPGE	Minimum production of grain equivalents, including irrigation (10^6 tonnes/year)

TABLE II

Actual and potential agricultural and irrigated land

	ACL	AIL	%	PAL	PIAL	%
World	1402	201	14·3	3419	470	13·7
India	142·8	34	24·5	142·8	77·6	54·3

ACL	:	Actual cultivated land (10^6 ha)
AIL	:	Actual irrigated land (10^6 ha)
PAL	:	Potential agricultural land (10^6 ha)
PIAL	:	Potential irrigable agricultural land (10^6 ha)

considering the fact that the same land is used for growing more than one crop (multiple cropping) in our country. The intensity of cropping can be as high as 400%, if there is adequate water and energy.

We have also modified the equation for determining the gross photosynthesis. In India, data on daily radiations are available from several locations (Ganesan[2]). Therefore, instead of using the number of sunny and cloudy days in the equation, we have used the average crop season radiation.

Methodology

The growth and productivity of crops are dependent upon the soil, water and nutrient availability, suitable ambient temperature and carbon dioxide at the field level. Depending upon the characteristics of the soil and the availability of water, reduction factors have been introduced. If a soil has good nutrient status and water holding capacity then no correction factor has been applied. The correction factor on the scale of 0 to 1·0 has been used for poor soil with respect to salinity or alkalinity or acidity, poor water holding capcity, etc. In the same way, a correction factor for water deficit has been used considering the water availability at different periods of crop growth. These scale s are similar to those used by Buringh *et al.*[1]. The ultimate yield of crops will also depend upon the protection provided against weeds, pests and pathogens.

The National Bureau of Soil Survey and Land Use Planning has prepared a soil map of India in which 25 different soil types have been characterised. In order to introduce some amount of simplification, the country was divided for the purpose of the present study into the following ten major soil type groups :

(1) Alluvial, (2) Black soil, (3) Red soil, (4) Red and yellow soil, (5) Brown, (6) Desert, (7) Hill soils, (8) Laterite, (9) Coastal includihg deltaic alluvial, (10) Mountain.

The area under each of these soil types was cut out of the map and measured on a leaf area meter (Model AAM 7). The proportionate area of different soil types was calculated considering the total reported land area of India as 304 million hectares. Based on the data for cultivated land in each state, the percentage of cultivated land for each soil type was estimated. The irrigated area in different states was used for determining the percentage of irrigated area under different soil types. In addition, the rainfall in different regions was also superimposed to determine the total water availability. This analysis was then utilised for deciding whether only one or more crops in a year could be grown in a year in a particular soil-climate zone. The rainfall and potential evapotranspiration data of 22 Centres under the All India Coordinated Research Project on Dryland Agriculture showed that with the exception of parts of Rajasthan and Gujarat, there is sufficient water available during the *kharif* season for one crop. Wherever irrigation is available there is a possibility of obtaining two or three crops in a year. The value of potential cropped area (PCA) reflects the extent of multiple cropping.

Dry matter production and yield

The following equation was used for determining the net photosynthesis as carbohydrates :

$$Pn = R \times DI \times 0{\cdot}32\ gm^2$$

where

Pn = Net photosynthesis as carbohydrates

R = Radiations per day (Photosynthetically active radiations)

0·32 = This factor was obtained following the radiation-carbohydrate production relationship derived by Loomis and Williams[3]. According to this 222 cal cm^2 day^{-1} of photosynthetically active radiation (PAR) can produce 71 g carbohydrate m^2 day^{-1}.

DI = The number of days in a crop season when 100% interception of light occurs.

$DI = DI_{100} + DI_{50-100} + DI_{10-50} + DI_{<10}$, where the subscript indicates the extent of interception. For a 150 days crop of wheat on the basis of growth analysis, it was calculated that there are 93 equivalent days with 100% interception. A *kharif* crop of 130 days was estimated to have 83 equivalent days with 100% interception.

Dry matter production was calculated using the following relationship (Penning de Vries *et al.*[4]) :

$$DM = 0{\cdot}65 \times Pn \text{ or}$$
$$DM = 0{\cdot}65 \times R \times DI \times 0{\cdot}32\ gm^{-2}$$

If there is any reduction factor relating to either soil or water, that is also indicated as follows :

$$DM = 0{\cdot}65 \times R \times DI \times 0{\cdot}32 \times FSC\ (\text{or } FWD)\ gm^{-2}.$$

In case there is no reduction factor, then for an average PAR of 209 cal cm^2 day^{-1} as occurring in Delhi during the *rabi* crop season, there is potential for producing 4·04 kg m^{-2} dry matter. This is equal to 40·4 tonnes phytomass ha^{-1} in one season. In fact, a dry matter yield of 19 tonnes ha^{-1} of wheat biomass has actually been obtained at Delhi (Aggarwal, Chaturvedi and Sinha, unpublished).

Maximum production of grain equivalent (MPGE)

The dry matter is partitioned between roots, straw and grain. It is assumed that roots account for 15% dry matter and of the remaining 85%, only 40% gets into grains. However, the grains have about 15% moisture at the time of harvest. Therefore, the following equation has been derived (maximum dry matter production).

$$MPGE = PCL \times MDMP \times 0{\cdot}34 \times 1{\cdot}15.$$

Thus, after computing the potential cropped land (PCL) which includes single or multiple dropping factor, the maximum grain equivalent production was computed for different soil zones (Table III).

Maximum production estimates

The above analysis indicates that the absolute maximum production of grain equivalent in India may be 4,572 million tonnes per year, as against 3,200 million tonnes per year computed for the Indian sub-continent by Buringh *et al.*[1]. The difference in the computation is possibly becuase of the following reasons :

(1) The analysis by Buringh *et al.*[1] was at the global level and consequently at a much wider macro-scale. The present estimate is at the national level, although the calculation is still at the macro-level. If such an analysis is made at the State and finally at the Block levels, more precise estimates can be obtained.

(2) The present analysis indicates that the soil zones 1, 2, 3, 4 and 9 are potentially very productive, some of which have not been utilized to a sufficient degree. Interestingly, the north-eastern region has a very high productivity potential.

TABLE III

Absolute maximum grain equivalent production in different soils

Soil zone	ACL	PCA	FSC	FWD	MPGE
1	36·49	109·47	..	..	1536
2	40·16	60·24	..	..	1235
3	24·87	32·33	0·8	..	530
4	17·64	35·28	0·9	..	669
5	10·29	10·29	0·7	0·8	115
6	2·25	2·25	0·6	0·8	23
7	1·39	1·39	0·6	0·8	13
8	2·38	7·14	0·7	0·8	29
9	7·11	21·33	0·9	..	413
10	1·00	1·00	0·6	0·7	6
					4572

ACL : Actual cultivated land (10^6 ha)
PCA : Potential cropped area (10^6 ha)
FSC : Factor for soil quality
FWD : Factor for water deficit

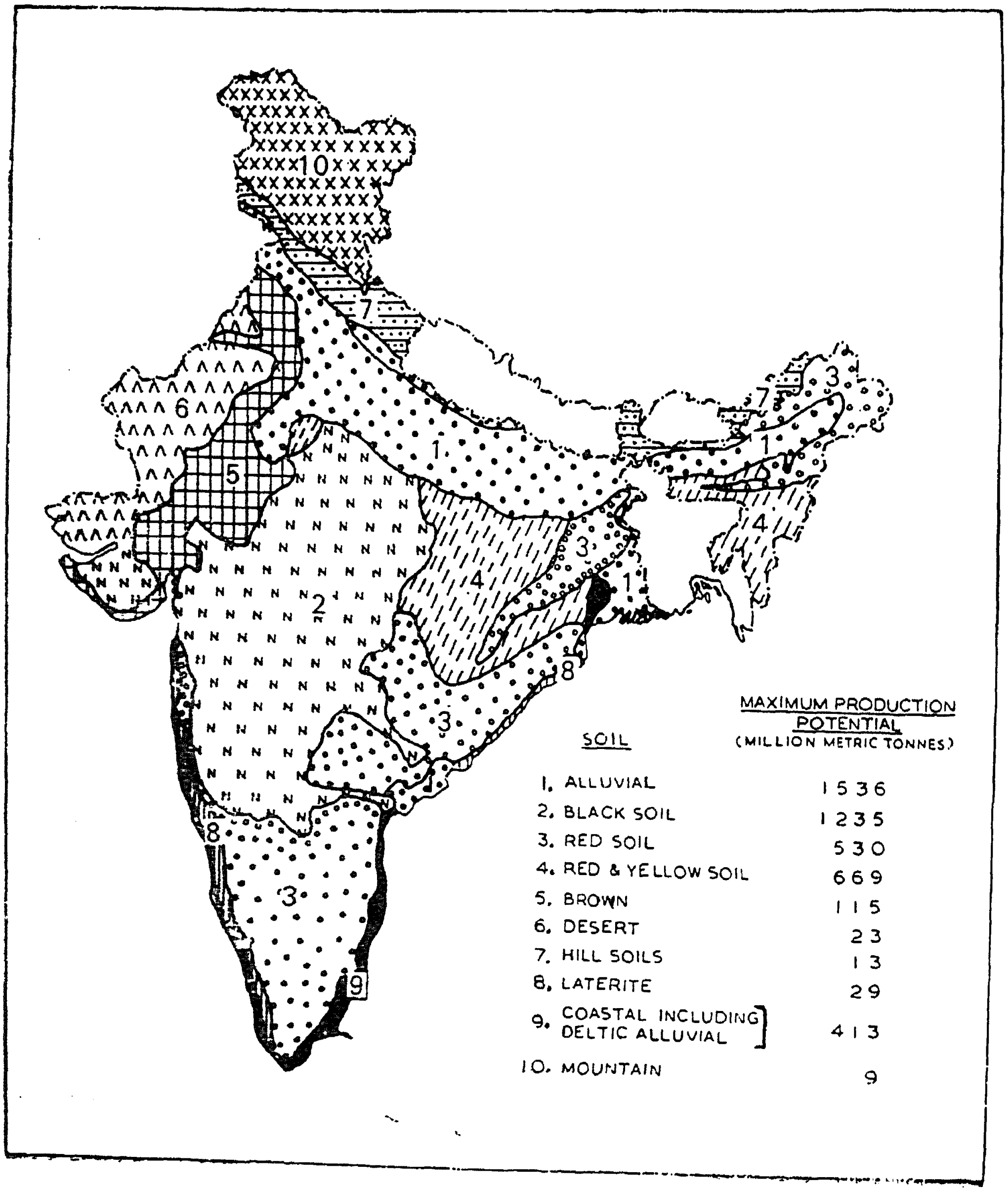

FIG. 1

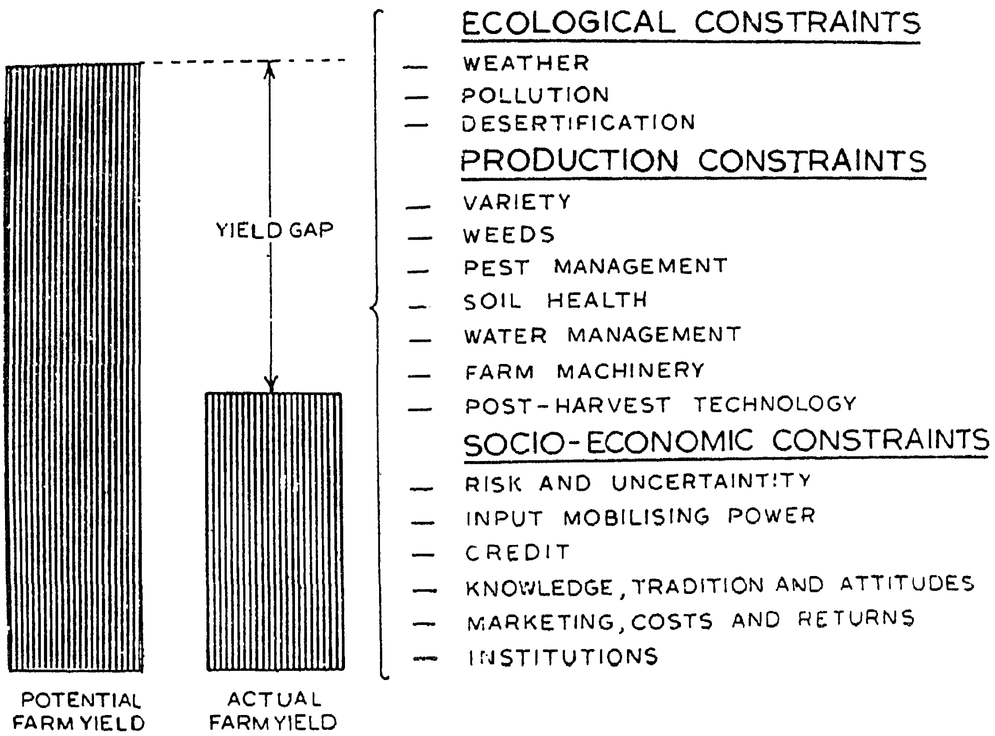

FIG. 2

(3) This analysis once again emphasises the need for proper land and water use planning (Swaminathan[5, 6]). The alluvial zone is ideal for the production of cereals such as wheat and rice, oil seeds and pulses, whereas the hill soils spread all along the foot hills of the Himalayas could become major horticultural and silvicultural zones. The soil zones 2 and 3 are very suitable for C_4 plants such as sugarcane, *Sorghum*, etc. whereas the coastal and laterite soil zones could remain the major areas for plantation crops and perennial oil seeds like coconut.

Limitations of the present study

The present study is based on a broad grouping of the various soil types. Very little data on water holding capacity, evapotranspiration and infiltration rates are available to determine precisely the amount of available water. This can be done when micro-level studies are undertaken. The correction factors for oil characteristics and water availability can be modified based upon precise local data. For example, in the alluvial soil zone, a considerable area is affected by salinity or alkalinity. Though several affected soils are not cultivated at present, such land can be reclaimed through appropriate soil amendments and drainage arrangements. The present study provides an approximate idea of the ceiling to food production possibilities in our country. The gap between potential and actual yields is very wide in most farming systems in the country. An inter-disciplinary constraints analysis (Fig. 2) will be necessary to identify the different constraints as well as their relative importance in influencing the size of the gap.

As stressed earlier, the maximum production potential data will have to converted for different crop mixes, according to energy-conversion relationships. Thus in soil zone I, if both cereals and oil seeds with 50% oil in the grain are produced, the absolute maximum production potential will be about 1,000 million tonnes of cereal grain and 268 million tonnes of oil seeds. If in Zones II and III, only sugarcane is grown, the production potential will be about 890 million tonnes of sugar, assuming 15% sugar content and 30% total dry matter. Zone 10 is capable of producing about 56 million tonnes of fruits, if all the available land is used for horticulture.

It is hoped that the present analysis will stimulate more detailed micro-level studies for the different districts and blocks of the country. The present macro-analysis has shown that we are endowed with a large untapped production reservoir. This provides hope for a bright agricultural future.

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