Indian Biologist, **Vol. 45 (1)**, pp 1 - 89 (2013)

CURRENT GLOBAL AGRICULTURAL SCENARIO AND PROJECTED CLIMATE CHANGE IMPACTS ON FOOD SECURITY IN THE LATE TWENTYFIRST CENTURY

R. N. BASU, A. K. MANDAL and S. RAY

Institute of Agricultural Science, University of Calcutta,
51/2, Hazra Road, Kolkata 700 019, West Bengal, India
e-mail : akmcu2002@gmail.com

Received on 12th March, 2013 *Accepted on 3rd April, 2013*

ABSTRACT

Earth's atmospheric temperature fluctuations, quite a number of times over some of the past geological periods have been attributed to certain natural events and causes. The ongoing phase of global warming owes its origin to the industrial revolution of the mid-18th century and is thus predominantly anthropogenic with progressively increasing emissions of greenhouse gases projected to become double of the preindustrial level of 280 parts per million (ppm) by the year 2085 or so. As a result, global temperature is likely to rise by around 3º Celsius with large latitudinal and regional deviations, by that time. The computerized general circulation models (GCMs) popularly known as climate models, besides projecting quantitative changes in temperature, have also predicted that, in general, tropical areas would have increased mean precipitation (with regional deviations), most of the subtropical areas would have decreased mean precipitation while in the high latitudes precipitation would increase; erratic behaviour of the pattern of precipitation would be a matter of concern especially in the tropical and subtropical regions.

Agricultural impact models such as Ricardian or Cross Section models and Agronomic or Crop models have been developed for prediction of climate change effects on agricultural production with or without carbon fertilization (CF) in view of the dual effect of carbon dioxide on global warming as a greenhouse gas (GHG) and its promoting effect at high concentrations on photosynthetic carbon assimilation, as a basic input of the process.

A total of 51 judiciously selected countries as representatives of diverse world agricultural scenario with respect to production of various agricultural commodities in 2010 (vide FAOSTAT database) in the crop and livestock sectors, total output of the countries, output per hectare, output per capita and other related attributes have been taken into consideration. For analysis of the full decadal (2001 – 2010) and first half-decadal (2001 – 2005) and second half-decadal (2006 – 2010) data of the 21st century, however, only 33 countries across the world have been considered. Although basic food grains such as rice, wheat, maize and soybeans dominate the crop sector, for a number of countries the top revenue earning crop could be other than the major grains, as for example, oil palm in Malaysia, sugarcane in Brazil, olives in Spain and Greece, grapes in Chile and Italy, tomatoes in Egypt and Iraq, plantains in Cameroon, etc. Globally, production of commodities in the

livestock sector is on the increase – the contribution in terms of dollar value (US $) of commodities, the share of the livestock sector is 51% against 49% share of the crop sector commodities. As a provider of food, the two cattle products, cow milk and cattle meat together account for 24% of global agricultural production of $1470 billion (share of cow milk $179 billion and cattle meat $168 billion; total $347 billion) in 2010. The contribution of countries like New Zealand and Norway to the livestock sector exceeds 90% of total agricultural output. It is over 80% in Switzerland, exceeds 75% in the Netherlands and about 74% in the UK and 72% in Germany and 69% in the Latin American country, Venezuela. The crop sector accounts for nearly 90% output in Cambodia, 89% in Indonesia, 88% in Sri Lanka, 87% in Bangladesh, 82% in Myanmar and 75% in Vietnam in all of which rice is the dominant crop. In India, the contribution of the crop sector is 67.5% and that of the milk-dominated livestock sector is 31.5%.

Country-wise total agricultural output in 2010 has been highest in China with $343 billion, followed by USA ($195 billion), India ($165 billion), Brazil ($115 billion), Indonesia ($51 billion), Argentina ($39 billion) and so on. Output per hectare, as derived by dividing total agricultural output (in US$) of a country by the total farm area of the country in hectares, has been the highest in the Netherlands ($6110/ha) generated mostly (over 75%) through livestock production exclusively through imported feed grains as the country does not raise grains. It is followed by crop sector dominated Egypt ($4057/ha) with only 3.9% of its land area cultivable with water from the Nile (100% irrigated) that is very efficiently used to raise bumper harvests from a range of crops. The next amongst the selected countries is Japan with an output of $3379/ha, followed by Belgium ($3287/ha), Vietnam ($2734/ha), Bangladesh ($2333/ha) and so on. The output/ha in India is $938/ha, a bit lower than China ($974/ha) but which is nearly double than that of USA ($494/ha), an acknowledged citadel of industrial agriculture. The output per hectare is lowest in Australia and Russian Fed. ($47/ha each).

Australia has the highest per capita arable land (21 ha/person attributed to huge land area and low population density) but because of very low output/ha ($47/ha), the country's fairly high output/capita ($951), is much lower than that of Uruguay ($2427/capita) with low population density but moderate output per hectare ($561/ha). As the cost of production is higher in the high income OECD countries than in the developing countries, the net income vis-à-vis output would be still lower in OECD countries most of which contribute to only 1 – 2% as the share of agriculture to their total national GDP and agriculture is grossly subsidized by the state.

Availability of basic food commodities namely, wheat, rice, maize and soybeans is crucial for food and nutritional security particularly for meeting the growing demand for animal proteins from livestock products such as meat, milk, egg, etc. that need lot of feed grains. As such, large quantities of food grains for humans are diverted as feed for livestocks.

The demand for more and more livestock products can hardly be met in the present changed circumstances and contexts. A critical perusal of the availability of meat, milk and egg vis-à-vis grain availability in the developing and developed countries would reveal the large disparity between them. Total meat production in the high income OECD countries and per capita availability are much higher than in the crop sector dominated developing countries in South and Southeast Asia, Sub-Saharan Africa and some Latin American countries. Per capita meat availability (composite meat of cattle, pig, chicken, sheep, etc.) in 2010 has been 300 kg in New Zealand, 208 kg in the Netherlands, 195 kg in Australia, 155 kg in Canada, 129 kg in the USA; the same has been 3.6 kg in Bangladesh, 4 kg in

India, 15 kg in Pakistan. Japan (with 25 kg per capita), Philippines (29 kg), Myanmar (30 kg), Cambodia (38 kg), Thailand (39 kg), Vietnam (43 kg), China (52 kg) are the other moderate meat eaters of Asia. The consumption of fish and allied marine products is, however, very high in Japan, over 40 kg/capita/year. Except South Africa (64 kg/capita), other African countries in the list of selected countries suffer from inadequate availability; in most other African countries meat availability ranges from 13 – 14 kg/capita/year. Situation in Latin America, except in Argentina (112 kg/capita) and Brazil (106 kg/capita), is generally low to moderate with considerable differences between the countries.

India is presently the highest milk producing country (130 mmt) in the World but because of its huge population, per capita availability is relatively low (107 kg/capita/yr). Milk availability per capita is exceptionally high in New Zealand with a whopping 3886 kg/person and serves as an important revenue-earning export commodity. As in case of meat, milk availability is high in the rich OECD countries like the Netherlands (705 kg/capita), Australia (423 kg), France (386 kg), Germany (340 kg), Norway (324 kg), USA (283 kg) and so on. Most countries in Southeast Asia are poor to very poor in milk availability. Japan (61 kg/capita) and China (30 kg) started cow milk consumption in post-World War II phase, in Bangladesh goat milk is the major source of milk (21 kg cow milk equiv., CME/capita), in Sri Lanka it is just 6.3 kg/person, in Myanmar (23 kg) but fairly high in Pakistan (240 kg/capita), almost at par with Canada (244 kg) and a bit lower than Argentina (258 kg/capita).

Availability of egg (shown as hen egg or hen equivalent egg per capita) in 2010 has been highest in the Netherlands (38.2 kg/capita/yr or 510 eggs of 'A' size 75 g each; 1 kg ≡ 13.3 eggs), followed by Thailand (402 eggs, hen equiv.; duck eggs an important source), China (378 eggs), Australia (293 eggs), Mexico (290 eggs), Japan (263 eggs), Spain (251 eggs), USA (230 eggs) and Canada (169 eggs/capita). Countries with low egg availability include Kenya (27 eggs/capita/yr), Cambodia (30 eggs), India (37 eggs), Pakistan (43 eggs), Vietnam (48 eggs), Bangladesh (49 eggs), Zambia (52 eggs), Myanmar (75 eggs) and Philippines (95 eggs/capita). In most developing countries, a large part of hen egg production is from backyard unorganized sectors (also eggs from ducks raised in small and medium water bodies very often in village commons), while that (hen eggs) in the West are from well organized and structured confined rearing systems.

Availability of grains, converted to wheat equivalent values for the sake of uniformity in comparative studies, shows that globally 437 kg of wheat equivalent grains could be available in 2010 per person and that could provide 39 kg of meat (composite), 105 kg of milk and 9.2 kg of egg (equivalent to 123 number of hen eggs), besides supplying in part the other food requirements of an average person (irrespective of age and other factors). If reaching the global average be fixed as the target for countries that are lagging behind the respective global averages in respect of specific commodities, the differences could be theoretically made up by providing additional feed grains necessary for the purpose. For the sake of convenience let us assume that the consumption pattern of all high income countries would remain unaltered, only those who are below the average consumption level would be reaching for the current global averages (only for certain commodities, from their commodity-wise deficit levels) for three major livestock products – meat, milk and egg. We would take up acutely meat and egg deficit India as an example. The difference between World average (38.5 kg/capita) and Indian average (4 kg/capita) in meat availability is equal to 34.5 kg. If the deficit is made up by chicken meat (broiler) which is the least energy intensive and cheapest meat, requiring only 2.3 kg of grains per kg of meat then additional grains required would be 34.5 x 2.3 = 79.4 kg per capita. Similarly for egg that requires 11 kg of grains for 1 kg of egg, the difference between world average (9.2 kg/capita) and Indian average (2.8 kg/capita) being 9.2 – 2.8 = 6.4 kg/capita, an additional 6.4 x 11 = 70.4 kg of grains would be required. As milk availability in India is 107 kg/capita a little above the world average of 105 kg/capita, the question of additional grains does not arise. The total additional grains amounting to 149.8 kg (for meat 79.4, for egg 70.4) would mean an approximate 53% increase in grain availability (a rise in wheat equivalent grain production from current 331 million metric tonnes by an additional 174.8 mmt to 506 mmt) which is next to impossible. The same would be true for many other grain deficient developing countries. Even maintaining status quo would be a difficult proposition.

Our estimates have shown that by 2085, global production of grains for food and feed may suffer a decline of 33%. That takes into account a 30% diversion of grains for non-agricultural purposes. Further, there is considerable doubt whether in practical agriculture in diverse edaphoclimatic conditions, the 10 – 15% boosting of production by high atmospheric CO_2 level (carbon fertilization effect) would be able to compensate the manifold adverse effects of global warming and climate change.

Strategies to meet the projected demand and supply must be met through control of population expansion in most developing countries, closing all sorts of leakages in the production systems and preventing pre- and post-harvest wastages. The goal of zero waste generation should be a national policy with vigorous implementation at local and regional levels. Though agriculture is as yet a rural issue, urban and periurban agriculture are very effective nutrition-supplementing options as has been shown elsewhere. India had a tradition of crop-livestock integrated agricultural system and the resurgence of the same has started but the scale must be raised enormously perhaps to the level of saturation of potential capacity. That itself may meet the projected deficit in the country, but the basic issue in the context of climate change is emission cut at the global level and the only way to achieve the same would be through adoption by all the important GHG emitters the international protocols on emission cuts and accept the policy of clean development mechanisms in all spheres of human activities.

The major historically polluting industrialized countries that had burnt over the years enormous quantities of fossil fuels and still continuing and adding to the global pool of GHG, more recently along with some of the front runner developing countries, must realize the gravity of the situation and come to a consensus on emission cuts. The rich industrialized countries that happen to be located in the higher latitudes and, as such, tend to gain from global warming in the short term may not be able to escape the onslaught in the long term, must clearly understand the potential danger before things become totally out of control when despite all their economic resources and technological capabilities, it would be too late to get out of the self-created over consumption and consumerism oriented nearly invincible trap.

PREAMBLE

Global climate change is a legacy of mid-18th-century's industrial revolution in the West. The pollution caused by industries has now spread widely and reached a big dimension posing a serious threat to the safety and security not only of the perpetuators of the crisis, the human beings, but also of virtually all constituents of the biosphere and ecosystems. Climate change is primarily attributable to the gaseous pollutants emanated by burning fossil fuels, carbon dioxide in particular, that along with methane, nitrous oxide and F-gases are undeniably responsible for global warming, and as a consequence, of climate change. Among the adverse effects of climate change, emerging as well as potential, that on agriculture is indeed the most persistent, long term, and difficult- to-negotiate issue. Agriculture is a highly complex subject, although there are certain basic principles and rules, the great dependence on edaphoclimatic conditions is universally acknowledged. Over the years, rather thousands of years, people who ushered in agrarian civilization brought about tremendous diversities in agricultural practices in different regions and countries, in tune with prevailing climatological conditions and available natural resources. The present predominantly top-down approach of conventional industry-modelled agriculture may nevertheless prove inadequate to tackle the problem, not only of rising ambient temperatures but also specifically of erratic climatological patterns with ever increasing uncertainties such as prolonged drought and high precipitation and flooding causing uncertainties, in raising crops and livestocks. As rainfed agriculture is still a major determinant of the success of agriculture (globally only about 2% land is irrigated as per World Development Indicators, 2010), eradication of poverty and hunger, specially in the low-income developing countries, a blue print for the future schedule must be worked out soon after critically assessing the projections and predictions related to impacts on agriculture.

In view of the fact that climate change is a global issue and as even the least greenhouse gas emitter may be the worst sufferer, it is imperative that a much wider perspective is involved and remedial measures would also require the participation of countries that are not immediately threatened. The current agricultural scenario in the world and the situation in a range of representative countries (if not all) need to be studied and analyzed in our attempt to search for alternative adaptive as well as mitigational strategies.

William R. Cline of the Peterson Institute of International Economics, Washington, USA in a comprehensive review and analysis in 2007 has covered the issues pertaining to the impact of global warming on agriculture of over one hundred countries of the world. His analysis confirms that in general agricultural production in the 2080s would be adversely affected. In spite of some initial advantages to the countries in the higher latitudes due to some positive effects such as warmer and longer growing season along with added benefits of carbon fertilization, in the long run those countries would also suffer from the adverse effects of climate change.

In the aforementioned excellent treatise Cline (2007) has provided countrywise data on annual production of agricultural commodities for the year 2003 in terms of US dollars (total output for a country) and very importantly agricultural output per hectare (in US $) obtained by dividing total value of products by the total farm area of the country as a measure of overall efficiency of the farming system of the country. While the total value of production in general was high in the big agricultural economies like China, USA, India, Brazil, etc. the output per ha (with the exception of China) was significantly more in middle or low order agricultural countries and economies. While China showed an impressive output per ha of 1381 $/ha in 2003 the same for USA was 260 $/ha, India 777 $/ha, Brazil 84 $/ha, Argentina 83 $/ha, Australia 29 $/ha, Russia 87 $/ha, Canada 254 $/ha, the European countries fared better with output of 800-1100 $/ha (small countries like the Netherlands demonstrating 4568 $/ha). The global median value for the year 2003 was better (380 $/ha) than that of the USA. What was surprising was the revelation that poor countries like India (777 $/ha), Pakistan (856 $/ha), Philippines (1054 $/ha), Vietnam (969 $/ha), Bangladesh (1355 $/ha), Sri Lanka (1808 $/ha) greatly outperforming the USA, a citadel of industrial agriculture in gross output/ha as well as net income/ha.

In the present paper, we have analyzed the more recent agricultural production data on the subject in greater details not only for total production but also to separate out the relative contribution of countries in the crop sector and livestock sector, in view of the growing contribution of the latter in agricultural production.

Finally, for the agricultural impact of climate change we have used the preferred estimates of Cline (2007) to assess the impact of global climate change in the late 2080s and have attempted quantification of the global food situation giving particular emphasis on developing countries with special focus on India as to food and nutrition security for the common people who are always on the odd side of any socioeconomic upheaval.

We have selected 51 countries of the world (subsequently reduced to 33) for the purpose and collected basic data from FAOSTAT database, 2010 World Development Indicators, Human Development Report, 2010 and various other sources for further calculations and analyses of primary data in light of observations on the subject from various authorities and particularly that of Cline (2007).

Major Observations : Countrywise and Global

Selection of countries for the study: It would have been the best option if we could take all the 155 countries listed under "Agricultural output and productivity" in section 3.3 of the '2010 World Development Indicators' for an overview of world agricultural scenario, but for obvious technical reasons we have selected about one third of them, only 51 countries for data on agricultural performance in 2010 as per the latest revised FAOSTAT database (complete version made available in 2012; accessed between March and July, 2012). For the first decadal and half-decadal data of the 21st century (2001-2010 and 2001-2005, 2006-2010), the number of countries selected have been further reduced to 33 only (18 of the 51 countries omitted). In both the aforesaid selections we have tried to make them as representative as possible in respect of the current agricultural developments and perspectives.

The alphabetically arranged 51 countries in Table 1 virtually represent the diverse geographic, economic and agricultural scenario of the world in that they come from all the continents covering the low latitudes in the tropics and subtropics to very high latitudes of the northern and southern hemisphere and longitudes from the near east to far west, countries socio-economically highly developed to very poorly developed ones with human development indices as high as 0.941 to as low as 0.425 (out of 1.0 that includes a wide range of human development subcomponents).

The distribution of countries shows inclusion of 5 from South Asia, 8 from East-Asia Pacific, 4 from Middle East and North Africa, 5 from Sub-Saharan Africa, 10 from Latin America and Caribbean, 15 of the OECD countries of Europe, North America (USA and Canada), Asia (Japan) and Australasia (Australia and New Zealand). Economically, 8 are low income countries, 11 low middle income, 15 upper middle income and 17 high income ones (OECD countries and Saudi Arabia).

Data in Table 2 show that along with very large countries such as Russia, China, USA, Canada and Brazil, we have a wide range of big and middle order countries followed by very small countries such as Belgium, the Netherlands, Switzerland with widely differing population (e.g. China 1353 million against Uruguay 3.4 million), GDP per capita (Norway with $56,214 in 2009 against $1004 of Madagascar) with respective human development ranking of No. 1 (HDI 0.941) and No. 149 (HDI 0.481) respectively. Interestingly in tune with the rest of the OECD countries in all high income economies the share of agriculture in GDP ranges between 1-2% (Table 2). The highest share of agriculture in total GDP has been that of Cambodia at 35%, followed by Nepal (34.7%) and Kenya (27%). Incidentally, India's per capita GDP in 2008 was $3296 and the share of agriculture in GDP was 17%; further, the Human Development Rank was as low as 134 with HDI value of 0.542 (Table 1). The lowest ranking in the list of 51 countries was that of Zambia at No. 165 with a very low HDI value of 0.425.

Top 20 commodities in the FAOSTAT database: The Food and Agriculture Organization of the United Nations database (FAOSTAT database) provides country-wise information on its website http://faostat.fao.org /site/339/default.aspx on a maximum of 20 commodities by value [production (Int $1000)] along with production (MT) and their respective graphical representations. We have used the data for the calculation of total agricultural production (summation of the total value of the production in US $), producer's price in dollars per metric tonne (mt), availability of a commodity per capita in kg per year by dividing the production by estimated population for the year, and share (contribution in%) of a commodity to the total production. The data provided in Table 3 show the 'top 5' agricultural commodities of each of the 51 countries for the year 2010 along with their cumulative and individual contributions. A summary of the nature and extent of contribution by all 20 items is provided elsewhere (Table 8). A perusal of the data on 'top 5' items show that nearly 45-90% of total output, depending on the country would be attributable to the first 5 items. The first commodity in over half the number of countries is a livestock-derived product such as cow milk, cattle meat and other meats with the rest nearly half of the countries showing a crop (with rice dominating in eleven countries out of 51) as the topmost commodity. It needs to be pointed out that Bangladesh depends on rice for over 66% of its total agricultural production, a really unparalleled status for any single item in any other country. Unconventional top commodities providing maximum revenue include palm oil (53.2%) in Malaysia, soybeans in Argentina (36.6%), olives in Greece (26.5%) and in Spain (23.7%), sugarcane in Brazil (20.3%), tomatoes in Egypt and Iraq (20%), grapes in Chile (22%) and Italy (17%), plantains in Cameroon (14.8%). Overall as a provider of food, the role of cattle, however, is overwhelming and almost universal and globally in 2010 the total agricultural production was $1470 billion and cow milk and cattle meat together constituted 23.6% (12.2% cow milk and 11.4% cattle meat) of that, amounting to a total of $347 billion ($179 billion cow milk, $168 billion cattle meat), the corresponding value for USA is 57.5 billion dollars ($27.2 billion for cattle meat + 30.3 billion for cow milk) accounting for 29.4% of the country's total agricultural output. For New Zealand, the contribution of cattle product is very high, 71.1% (cow milk 53.6% + cattle meat 17.5%). In Switzerland the contribution by cattle products is also as high as 59.1%, for Norway (the top country in HDR) it is 54.9%; the same for Australia is 43.2% and Netherlands 33.9% of the respective country's total agricultural production.

Table 1.

The selected 51 countries , their regional and economic grouping along with UNDP Human Development Ranking (HDR) and Index (HDI) for the year 2010

Country	Regional Group	Economical Group	HDR	HDI	Country	Regional Group	Economical Group	HDR	HDI
Algeria	MENA	UMC	96	0.696	**Malaysia**	EAP	UMC	64	0.761
Argentina	LAC	UMC	46	0.794	**Mexico**	LAC	UMC	57	0.767
Australia	OECD	HIC	2	0.927	**Myanmar**	EAP	LIC	150	0.479
Bangladesh	SA	LIC	146	0.496	**Nepal**	SA	LIC	156	0.455
Belgium	OECD	HIC	18	0.885	**Netherlands**	OECD	HIC	3	0.909
Bolivia	LAC	LMC	108	0.660	**New Zealand**	OECD	HIC	5	0.908
Brazil	LAC	UMC	85	0.715	**Norway**	OECD	HIC	1	0.941
Cambodia	EAP	LIC	141	0.518	**Pakistan**	SA	LMC	145	0.503
Cameroon	SSA	LMC	151	0.479	**Peru**	LAC	UMC	81	0.721
Canada	OECD	HIC	6	0.907	**Philippines**	EAP	LMC	112	0.641
Chile	LAC	UMC	44	0.802	**Portugal**	OECD	HIC	40	0.808
China	EAP	LMC	101	0.682	**Russian Fed**	ECA	UMC	66	0.751
Colombia	LAC	UMC	88	0.707	**Saudi Arabia**	OTHER	HIC	58	0.767
Cuba	LAC	UMC	51	0.773	**South Africa**	SSA	UMC	124	0.615
Egypt	MENA	LMC	112	0.644	**Spain**	OECD	HIC	23	0.876
France	OECD	HIC	20	0.883	**Sri Lanka**	SA	LMC	98	0.686
Germany	OECD	HIC	9	0.903	**Switzerland**	OECD	HIC	11	0.901
Greece	OECD	HIC	29	0.862	**Thailand**	EAP	LMC	103	0.680
India	SA	LMC	134	0.542	**Turkey**	ECA	UMC	95	0.696
Indonesia	EAP	LMC	125	0.613	**United Kingdom**	OECD	HIC	28	0.862
Iran	MENA	UMC	87	0.707	**United States**	OECD	HIC	4	0.908
Iraq	MENA	LMC	132	0.567	**Uruguay**	LAC	UMC	48	0.780
Italy	OECD	HIC	24	0.873	**Venezuela**	LAC	UMC	73	0.734
Japan	OECD	HIC	12	0.899	**Vietnam**	EAP	LIC	128	0.604
Kenya	SSA	LIC	144	0.505	**Zambia**	SSA	LIC	165	0.425
Madagascar	SSA	LIC	149	0.481					

Note 1 : The regional groups are : East Asia and Pacific (EAP), Europe and Central Asia (ECA),Latin American and Caribbean (LAC),Middle East and North Africa (MENA), South Asia (SA), Sub-Saharan Africa (SSA), Organization of Economic Cooperation and Development (OECD) and other high income (OHIC).

Note 2 : Economically the countries have been classified under Low Income (LIC),Lower Middle Income (LMC) ,Upper Middle Income (UMC) and High Income (HIC) categories.The income groups based on per capita per year earning are as follows : Low Income (LIC) : $ 1005 or less, Lower Middle Income (LMC) :$ 3976- $ 12275; Upper Middle Income (UMC): $3976- $12275; and High Income (HIC): $ 12276 and above.

Overall production: An analysis of the overall performance of the 51 countries, as presented in Table 4, show the undisputed supremacy of China in agricultural output amounting to over $343 billion in 2010 followed distantly by the USA with $195 billion, India $165 billion and Brazil at $115 billion way ahead of Indonesia at $51 billion, Argentina $3.9 billion, Russian Federation $35 billion, France $34 billion, Pakistan $32 billion and Germany $29 billion. Besides the aforesaid 10 countries (including the last six middle order economies), we can mention Mexico $28 billion, Spain $27 billion, Thailand $26 billion, Vietnam $26 billion, Italy $25 billion, Turkey $25 billion, Canada $24 billion, Australia $21 billion, Bangladesh $20 billion and Iran $19 billion as 10 more middle to low middle order agricultural producers.

Output per capita: The highest per capita output (Table 4) is that by Uruguay ($2427) attributable to the high per capita availability of agricultural land per person (4.32 ha/capita; if only rural population is considered it is 54 ha/capita) followed by Australia and Argentina with $989 and $951 respectively. It is worthwhile to mention here that the per capita availability of land in Australia is very high at 21 ha/person while considering rural population only, the same is a staggering 191 ha /person. Because the output per ha is very low ($47/ha) the country falls behind Uruguay in output per capita despite a very low population density. On the other extreme is the situation in Bangladesh with the per capita output of $123 simply because availability of land is very low, only 0.05 ha per capita due to high population density but the high output per ha considerably compensates the alarming situation. The same is true for Japan but the country is economically very strong (one of the high income OECD countries) compared to the poor economic strength of Bangladesh which still depends so much on agriculture. Because of its huge population the output per capita in India is also very low; further its output per ha is much lower than that of Bangladesh. Despite its overall supremacy in agricultural production, the per capita output ($254) of China is moderate because of its huge population of nearly 1.4 billion and considering the vast area under cultivation and output per ha of $974 (nearly double than that of USA) must be appreciated and a strong agricultural economy with considerable focus on food and nutrition given due recognition. In general, output per ha is more in smaller moderate to thickly populated countries with favourable edaphoclimatic conditions.

It is considered very important to point out here that we have taken the average of farm area of Cline's 2007 publication (based on 2003 FAOSTAT data) and that of 2010 World Development Indicators (expressing therein the agricultural land as percentage of total land area in 2008). This average area is more or less similar to 2003 data of Cline (2007) for majority of 51 countries selected but show large increases in farm area in case of the following countries; Algeria (+190%), China (+129%), Kenya (+ 209%), Madagascar (+523%), Russia (+202%), South Africa (1276%), Zambia (+193%). Those not included by Cline (2007) but covered by 2010 World Development Indicators would remain unchanged. As such total output of the country would remain the same, while the per hectare production would go down considerably with increase in farm area. It would appear that large portions of marginal or submarginal land or forest land (such as huge tracts of forest in Latin America, Africa and elsewhere) have been converted to lands for grazing. Deserts are advancing in many countries but in many areas there are reports of greening and gradual

Table 2.

Some important development indicators of the selected 51 countries in relation to current agricultural production scenario

Country	Land Area ('000 sq km)	Estimated population in 2010		GDP per capita in 2009 ($PPP)	Share of Agric in total GDP in 2008 (%)	Estimated agric. land (million ha)	Estimated share of agri. Land in agric. land (%)
		(million)	(% rural)				
Algeria	2381.7	35.4	35	8172	7	24.474	10.3
Argentina	2736.7	40.7	8	14538	10	151.734	55.4
Australia	7682.3	21.3	11	39539	3	446.807	58.2
Bangladesh	130.2	166.1	78	1416	19	8.772	67.4
Belgium	30.3	10.8	3	36313	1	1.411	46.6
Bolivia	1083.3	10	34	4419	13	36.832	34
Brazil	8459.4	198.3	14	10367	7	307.926	36.3
Cambodia	176.5	15.3	78	1915	35	4.64	26.3
Cameroon	472.7	19.6	43	2205	19	8.071	17.1
Canada	9093.5	33.8	20	37808	–	65.58	7.2
Chile	743.8	17.1	12	14311	4	21.061	28.3
China	9327.5	1352.9	57	6828	11	352.14	37.8
Colombia	1190.5	47.7	26	8959	9	46.434	39 .0
Cuba	109.8	11.3	24	–	–	4.888	44.5
Egypt	995.5	79.3	57	5673	13	3.867	3.9
France	547.7	62.2	23	33674	2	29.737	54.3
Germany	348.8	82.3	26	36338	1	18.098	51.9
Greece	128.9	11.2	39	29617	3	6.063	47 .0
India	2973.2	1216.6	71	3296	17	175.74	59.1
Indonesia	1811.6	238.9	49	4199	14	41.307	22.9
Iran	1628.6	74.1	32	11558	10	32.159	19.8
Iraq	437.4	31.5	30	3548	–	7.107	16.2
Italy	294.1	58.9	32	32430	2	17.009	57.8
Japan	364.5	127.3	34	32418	1	4.751	13 .0
Kenya	569.1	40.5	78	1573	27	15.955	28 .0
Madagascar	581.5	21.2	71	1004	25	22.128	38.1
Malaysia	328.6	27.8	30	14012	10	7.736	23.5
Mexico	1944	109.6	23	14258	4	145.38	74.8
Myanmar	653.5	49.9	67	-	-	11.187	17.1
Nepal	143.4	29.8	83	1155	34	3.787	26

Contd.

Country	Land Area ('000 sq km)	Estimated population in 2010		GDP per capita in 2009 ($PPP)	Share of Agric in total GDP in 2008 (%)	Estimated agric. land (million ha)	Estimated share of agri. Land in agric. land (%)
		(million)	(% rural)				
Netherlands	33.8	16.5	18	40676	2	2.083	61.6
New Zealand	267.7	4.4	13	28993	-	13.977	52.2
Norway	304.3	4.9	23	56214	1	0.913	3
Pakistan	770.9	173.9	64	2609	20	24.551	31.8
Peru	1280	29.4	29	8629	7	28.571	22.3
Philippines	298.2	92.6	35	3542	15	11.106	37.2
Portugal	91.5	10.7	41	24920	2	4.379	47.9
Russian Fed.	16377.7	140.4	27	18932	5	755.732	46.1
Saudi Arabia	2000	26.2	18	23480	2	4.046	2.1
South Africa	1214.5	49.1	39	10278	3	59.473	49
Spain	499	44.6	23	32150	3	35.562	71.3
Sri Lanka	64.6	19.5	85	4772	13	2.153	35.1
Switzerland	40	7.7	27	45224	1	1.56	39
Thailand	510.9	64.9	67	7995	12	19.646	38.4
Turkey	769.6	77.5	34	13668	9	34.271	44.5
United Kingdom	241.9	61.4	10	35155	1	16.973	70.2
United States	9161.9	309.5	18	45989	1	395.815	48.2
Uruguay	175	3.4	8	13189	11	14.7	84
Venezuela	882.1	28.9	7	12323	-	25.621	29
Vietnam	310.1	90.7	72	2953	22	9.409	30.3
Zambia	743.4	12.6	65	1430	21	15.467	20.8
World	129611.3						

conversion of semidesert land to agricultural lands. The 2010 World Development Indicator gives the amount of agricultural land area in China as 59% of land area in 2005-07 which would be 59% of 9327.5 thousand square km (= 5503225 sq. km or 550 million hectare as against 2003 FAO figure of 153.96 million ha covering 16.5% of the total land area). We have taken average of the two sets of values as a consensus and pragmatic approach. The revised farm area (agricultural land) and production ($) per hectare have been shown in Table 2 (column 7) and Table 4 (column 7) respectively.

Output per hectare: Output per ha (in US $) is an effective measure of the efficiency of the farming systems and practices of a country. This is obtained by adding the total valuation of all the agricultural commodities produced by a country (usually a maximum of 20 products) and then dividing the same by the total farm area of the country in hectares (Table 2, 4). The highest per ha output in 2010, among the selected 51 countries, has been that of the Netherlands ($6110/ha), followed by Egypt ($4057/ha), Japan ($3379/ha), Belgium ($3287/ha), Vietnam ($2734/ha), Bangladesh

Table 3.

Top five (5) agricultural products (valued in US $) of the 51 selected countries; the share (% of total) of each commodity within a country to total agricultural production for the year 2010 is given in parenthesis ; the column after a country shows the total value of 5 commodities in US dollars and the next coulmn shows the share of the top 5 commodities as percentage of each country's total produce

Sl. No	Countries	Total value of 5 items (million $)	Cumulative share of 5 commodities (%)	Top 5 commodities with respective share (%)
1	**Algeria**	2493	44.9	cow milk (10.2), potatoes (9.6), sheep meet (8.8), wheat (8.3), olives (8.0)
2	**Argentina**	29633	76.6	soybeans(36.6), cattle meat (18.3), cow milk (8.5), maize (7.2), wheat (6.0)
3	**Australia**	14845	70.5	cattle meat (29.9), cow milk (13.3), wheat (13.3), sheep meat (8.0), chicken meat ()
4	**Bangladesh**	16905	82.6	rice (66.4), potatoes (6.2), goat milk (4.1), mangoes etc (3.1), goat meat (2.3)
5	**Belgium**	3314	71.4	pig meat(35.0), cattle meat (12.8), chicken meat (10.8), potatoes (8.7), sugar beat (4.1)
6	**Bolivia**	1729	66	cattle meat (25.6), soybeans (15.1), sugarcane (9.3) chicken meat (9.1), pig meat (6.9)
7	**Brazil**	11158	72.6	sugarcane (20.3), cattle meat (16.8), soybean (13.8), chicken meat (13.2), cow milk (8.5)
8	**Cambodia**	3114	86.8	rice (61.5), cassava (12.4), maize (5.3), cattle meat (4.7), pig meat (2.9)
9	**Cameroon**	1680	46.2	plantains (14.8), cattle meat (8.9), cassava (7.8), cocoa beans (7.5), bananas (7.4)
10	**Canada**	16911	70.9	cattle meat (18.1), pigmeat (15.6), rape seed (13.8), wheat ((12.6), cow milk (10.8)
11	**Chile**	4360	63.1	grapes (22.8), pigmeat (15.6), cow milk (11.1), chicken meat (10.4), cattle meat (8.2)
12	**China**	185617	54.1	pig meat (23.1), rice (14.2), vegetables (6.1), hen eggs (5.8), chicken meat (4.9)
13	**Colombia**	7538	63	cattle meat (21.1), cow milk (18.8), chicken meat (12.0), sugarcane (5.6), rice (5.5)
14	**Cuba**	1167	54.1	sugarcane (15.9), pig meat (12.3), cow milk (9.1), tomatoes (8.9) cattle meat (7.9)
15	**Egypt**	7471	47.6	tomatoes (20.1), rice (7.3), cattle meat (7.0), buffalo milk (6.9), chicken meat (6.2)
16	**France**	23031	67.3	cow milk (20.9), wheat (13.4), cattle meat (13.3), pig meat (9.9), grapes (9.9)
17	**Germany**	21764	75.5	cow milk (29.2), pig meat (22.1), cattle meat (12.8), wheat (6.1), potatoes (5.5)
18	**Greece**	3223	59.1	olives (26.6), grapes (10.5), tomatoes (9.5), peaches and nectarines (6.4),sheep milk (6.1)
19	**India**	94578	57.4	rice (19.5), buffalo milk (15.1), cow milk (9.5), wheat (7.4), mangoes (5.9)
20	**Indonesia**	35340	69.3	rice (35.2), palm oil (18.4), natural rubber (6.3), cassava (4.8), chicken meat (4.6)
21	**Iran**	9676	50.8	chicken meat (12.3), cow milk (10.5), tomatoes (10.2), wheat (10.1), pistachios (7.7)
22	**Iraq**	1067	55.6	tomatoes (19.5), dates (12.2), wheat (19.2), cattle meat (7.0), sheep meat (6.7)
23	**Italy**	15116	60.4	grapes (17.8), cow milk (13.1), olives (10.1), pig meat (9.8), cattle meat (9.6)
24	**Japan**	1397	71	rice(18.3), cow milk (14.9), hen eggs (13.0), chicken meat (12.4), pig meat (12.4)

Contd.

Sl. No	Countries	Total value of 5 items (million $)	Cumulative share of 5 commodities (%)	Top 5 commodities with respective share (%)
25	**Kenya**	4056	68.7	cow milk (27.3), cattle meat (21.2), maize (7.4), tea (7.2), mangoes etc (5.6)
26	**Madagascar**	2350	73.6	rice (39.4), cattle meat (12.7), cassava (9.8), cow milk (6.9), mangoes etc (4.8)
27	**Malaysia**	12135	87.4	palm oil (53.2), chicken meat (14.2), palm kernels (8.0), natural rubber (7.1), rice (4.9)
28	**Mexico**	16208	58.5	cattle meat (19.1), chicken meat (13.8), cow milk (12.0), hen eggs (7.1), pig meat (6.5)
29	**Mayanmar**	12028	73.6	rice(49.8), beans (8.0), chicken meat (7.2), pig meat (4.3), vegetables (4.3)
30	**Nepal**	2859	64.1	rice (23.3), vegetables (12.7), buffalo meat (9.8), buffalo milk (9.5), potatoes (8.8)
31	**Netherlands**	10003	78.6	cow milk (28.5), pig meat (27.0), chicken meat (9.4), potatoes (8.3), cattle meat (5.4)
32	**New Zealand**	8927	90.4	cow milk (53.6), cattle meat (17.5), sheep meat (13.0), wool(3.2), kiwi fruit (3.1)
33	**Norway**	1064	84.5	cow milk (37.0), cattle meat (17.9), pig meat (15.7), chicken meat (8.6), sheep meat (5.3)
34	**Pakistan**	20372	62.8	buffalo milk (26.0), cow milk (11.4), wheat (10.5), cotton lint (8.6), buffalo meat (6.3)
35	**Peru**	3755	55.2	chicken meat (21.4), rice (11.5), potatoes (7.9), cow milk (7.0), cattle meat (6.8)
36	**Philippines**	12003	64.1	rice(22.2), pig meat (13.2), bananas (12.3), coconuts (9.1), tropical fruits (7.3)
37	**Portugal**	2586	68.1	cow milk (16.1), grapes (14.2), tomatoes (13.7), pig meat (12.6), chicken meat (11.5)
38	**Russian Fed.**	24618	69.8	cow milk (25.1), cattle meat (13.1), wheat (11.6), chicken meat (10.2), pig meat (9.3)
39	**Saudi Arabia**	2269	67.2	chicken meat (24.1), dates (16.3) cow milk (15.4), wheat (6.0), tomatoes (5.4)
40	**South Africa**	8153	65.7	cattle meat (21.9), chicken meat (17.1), maize (10.6), cow milk(8.1), grapes(8.5)
41	**Spain**	18764	69.3	olives (23.7) pig meat (19.9), grapes (12.9), cow milk (7.1) tomatoes (5.7)
42	**Sri Lanka**	2016	75.9	rice (44.0), tea (11.3), coconut (9.8), natural rubber (6.0), chicken meat (5.7)
43	**Switzerland**	2029	82.5	cow milk (43.5), cattle meat (15.6), pig meat (15.6), grapes (3.9), chicken meat (3.9)
44	**Thailand**	2016	67.6	rice (30.4), natural rubber (13.4), cassava (8.8), sugarcane (8.7), chicken meat (6.7)
45	**Turkey**	14320	57.5	cow milk (15.6), tomatoes (12.7), wheat (11.0), grapes (9.8), chicken meat (8.4)
46	**United Kingdom**	10795	70.6	cow milk (28.8), cattle meat (14.9), chicken meat (12.3), wheat (7.9), pig meat (6.7)
47	**United States**	131281	67.2	cattle meat (15.5), cow milk (13.9), maize (13.7), soybean (12.2), chicken meat (11.9)
48	**Uruguay**	3024	36.7	cattle meat (18.6), cow milk (6.2), soybeans (5.8), rice (3.8), wheat (2.3)
49	**Veneuela**	3685	67.3	chicken meat (21.6), cattle meat (18.3), cow milk (13.1), rabbit meat (8.6), sugarcane (5.7)
50	**Vietnam**	18829	73.2	rice (41.6), pig meat (18.7), vegetables (4.9), coffee green (4.6), cashew nuts (3.9)
51	**Zambia**	949	63.9	maize (26.1), cattle meat (11.1), tobaco (9.6), sugarcane (9.0), cassava (8.1)
	WORLD	811600	55.2	cow milk (12.2), rice(11.9), cattle meat (11.9), pig meat (11.4), chicken meat (8.3)

Table 4.

Total agricultural output , agricultural output per capita, output per hectare, and relative contribution of the crop and livestock sectors in the selected 51 countries

Sl. No	Countries	Total Agricultural output (million $)	Agricultural output/ capita ($)	Agricultural Land available per capita		Output per ha ($)	Crop Sector (CS)			Livestock Sector (LS)		
				General (ha)	Rural (ha)		CS (total) (million $)	CS (%)	CS / ha ($)	LS (total) (million $)	LS (%)	LS / ha ($)
1	Algeria	5,551	157	0.69	1.98	227	3,640	656	149	1,911	34.4	78
2	Argentina	38,686	951	3.73	4.66	255	25,223	65.2	166	13,463	34.8	89
3	Australia	21,057	989	21	190.9	47	7,623	36.2	17	13,434	63.8	30
4	Bangladesh	20,466	123	0.05	0.072	2333	17,703	86.5	2,018	2,763	13.5	315
5	Belgium	4,635	429	0.13	4.35	3287	1,614	34.8	1,144	3024	65.2	2,143
6	Bolivia	2,620	262	3.68	10.83	71	1,335	51	36	1,285	49	35
7	Brazil	115,369	582	1.55	11.09	375	64,491	55.9	209	50,878	44.1	165
8	Cambodia	3,547	234	0.3	0.39	773	3,218	89.7	694	369	10.3	80
9	Cameroon	3,637	186	0.41	0.96	451	2,968	81.6	368	669	18.4	83
10	Canada	23,852	706	1.94	9.7	364	11,163	46.8	170	12,689	53.2	193
11	Chile	6,911	404	1.23	10.26	328	3,884	56.2	184	3,027	43.8	144
12	China	343,099	254	0.26	0.46	974	186,989	54.5	531	156,110	45.5	443
13	Colombia	11,965	251	0.97	3.74	258	5,049	42.2	109	6,916	57.8	149
14	Cuba	2,157	191	0.43	1.8	441	1,387	64.3	284	770	35.7	158
15	Egypt	15,689	198	0.05	0.09	4057	10,747	68.5	2,779	4,942	31.5	1,278
16	France	34,222	547	0.48	2.08	1151	15,023	43.9	505	19,199	56.1	646
17	Germany	28,827	350	0.22	0.85	1593	8,129	28.2	449	20,698	71.8	1,144
18	Greece	5,457	487	0.54	1.39	900	3,833	70.2	632	1,624	29.8	268
19	India	164,770	135	0.14	0.2	938	111,220	67.5	633	53,550	32.5	305
20	Indonesia	50,995	213	0.17	0.35	1235	45,335	88.9	1,098	5,660	11.9	137
21	Iran	19,073	257	0.43	1.36	593	11,683	61.3	363	7,390	38.7	230
22	Iraq	1,922	61	0.23	0.73	270	1,463	76.1	206	459	23.9	65
23	Italy	25,027	425	0.29	0.9	1471	14,265	57	839	10,762	43	633
24	Japan	16,052	126	0.04	0.11	3379	6,228	38.8	1,310	9,824	61.2	2,068
25	Kenya	5,904	146	0.39	0.51	370	2,751	46.6	172	3,153	53.4	198
26	Madagascar	3,193	151	1.04	1.47	144	2,408	75.4	109	785	24.6	35

Contd.

Sl. No	Countries	Total Agricultural output (million $)	Agricultural output/ capita ($)	Agricultural Land available per capita		Output per ha ($)	Crop Sector (CS)			Livestock Sector (LS)		
				General (ha)	Rural (ha)		CS (total) (million $)	CS (%)	CS / ha ($)	LS (total) (million $)	LS (%)	LS / ha ($)
27	Malaysia	13,889	500	0.28	0.93	1,795	10,795	77.7	1,395	3,094	22.3	400
28	Mexico	27,706	253	1.33	5.77	191	11,526	41.6	79	16,180	58.4	111
29	Myanmar	16,343	328	0.22	0.33	1,461	13,336	81.6	1,192	3,007	18.4	269
30	Nepal	4,460	150	0.13	0.15	1,197	396	71.7	858	1,264	28.3	339
31	Netherlands	12,727	771	0.13	0.7	6,110	3,144	24.7	1,509	9,583	75.3	4,601
32	New Zealand	9,885	224	3.18	24.44	707	861	8.7	62	9,024	91.3	646
33	Norway	1,258	257	0.19	0.81	1,378	117	9.3	128	1,141	90.7	1,250
34	Pakistan	32,400	187	0.14	0.22	1,321	13,463	41.5	548	18,977	58.5	773
35	Peru	6,789	231	0.97	3.35	238	3,938	58	138	2,851	42	100
36	Philippines	18,720	202	0.12	0.34	1,699	13,722	73.3	1,246	4,998	26.7	454
37	Portugal	3,800	355	0.41	1	868	1,770	46.6	404	2,030	53.4	464
38	Russian Fed.	35,270	251	5.38	19.9	47	12,415	35.2	16	22,855	64.8	30
39	Saudi Arabia	3,382	129	0.15	0.86	836	1,628	48.1	402	1,754	51.9	434
40	South Africa	12,410	253	1.21	3.11	209	4,939	39.8	83	7,471	60.2	126
41	Spain	27,077	607	0.8	3.47	761	16,003	59.1	450	11,074	40.9	311
42	Sri Lanka	2,656	136	0.11	0.13	1,234	2,348	88.4	1,091	308	11.6	143
43	Switzerland	2,456	319	0.2	0.75	1,574	473	19.3	303	1,983	80.7	1,271
44	Thailand	26,034	401	0.3	0.45	1,325	20,124	77.3	1,024	5,910	22.7	301
45	Turkey	24,921	322	0.44	1.3	727	6,746	67.2	489	8,175	32.8	239
46	UK	15,291	249	0.28	2.8	901	4,052	26.5	239	11,239	73.5	662
47	USA	195,359	631	1.28	7.1	494	91,623	46.9	231	103,736	53.1	262
48	Uruguay	8,251	2427	4.32	54.04	561	5,813	70.5	395	2,438	29.5	166
49	Venezuela	5,478	190	0.89	12.75	214	1,712	31.3	67	3,766	68.7	147
50	Vietnam	25,723	284	0.1	0.14	2,734	19,164	74.5	2,037	6,559	25.5	697
51	Zambia	1,485	118	1.23	1.89	96	1,068	71.9	69	417	28.1	27
	WORLD	1,470,289	214	0.45	0	475	721,448	49.1	233	748,841	50.9	242

($2333/ha), Malaysia ($1795/ha), Philippines ($1699/ha),Germany ($1593/ha) and Switzerland ($1574/ha). Countries showing output/ha between $1500 -1000 /ha are Italy ($1471/ha), Myanmar ($1461 /ha), Norway ($1378/ha), Thailand ($1325/ha), Pakistan ($1321/ha),Indonesia ($1235/ha), Sri Lanka ($1234/ha), Nepal ($1179/ha) and France ($1151/ha), countries like China ($974/ha), India ($938/ha), U.K ($901/ha), Portugal ($868/ha), Cambodia ($773 /ha), Spain ($761/ha), Turkey ($727/ha), New Zealand ($707/ha) are of medium level productivity/ha. The output per ha in the USA is low intermediate ($494/ha), two other relatively large agricultural producers, Brazil and Argentina show agricultural output of $375/ha and $255/ha respectively; that of Mexico, a fairly big producer is low, only $191/ha. Still lower output /ha is noted in Zambia ($96/ha) and Bolivia ($71/ha) but the lowest output/ha among the 51 countries selected in this study is that by Australia and Russian Federation both showing $47 output /ha.

Relative share of crop and livestock sectors: The relative share of the crop and livestock sector is a very important characteristic of agriculture of developed countries where increasing emphasis is given to production of livestock based commodities; in fact more progressive agriculture means reducing the share of crop sector and increasing that of the livestock sector. A perusal of the data in Table 4 would show the livestock sector contribution of some countries as follows: New Zealand 91.3% (crop sector 8.7%), Norway 90.7%, Switzerland 80.7%, Netherlands 75.3%, UK 73.5%, Germany 71.8%, Belgium 65.2%, Portugal 64.5%, Australia 63.8%, Japan 61.2% and so on, all of which are OECD members with high incomes; even countries of the upper middle income group such as Venezuela (68.7%), Russia (64.8%), South Africa (60.2%) and many others are giving considerable emphasis on livestock production. The question of countries with big agricultural economies such as China, USA, India, Brazil and Argentina which do not show such large increases in relative contribution of livestocks are different. China's fascination with pig meat (the topmost agricultural commodity with 23.1% share of countries total agricultural production) valued at 79 billion dollars would have been 139 billion dollars if the same was cattle meat greatly raising its livestock share from its present 45.5% LS contribution to 53.6%, further China's consumption of fruits and vegetables has always been high. USA's annual availability of meat (composite) is very high 128 kg/person (which for obvious health reasons should not be increased further). Besides its big crop sector is dominated by grains that are mostly used as animal feed. Further nearly half of US corn production now goes for subsidized bioethanol production making more grain production obligatory. Regarding the third largest agricultural economy, India with a livestock share of 32.5%, it is really not possible to divert large quantity of grains from human food to animal feed as per capita availability of grains, rice in particular, is already less than what it was a decade back with rising population offsetting little gains (occasional monsoon favoured gains) in productivity. In this context it is worthwhile to point out that India is the only country where vegetarianism is still a very strong socio-religious institution in vast areas of the country. Beef and pork eating is a taboo with majority of Indians but milk is a highly preferred commodity and cow and buffalo milk together account for 24.6% (valued at $41 billion) of total agricultural output , the highest in the world (because of over 1.2 billion population the per capita availability is, however, low). Regarding Brazil, the country is a net exporter of soybeans and its top agricultural product sugarcane is a source of commercially successful bioethanol production for transport. Argentina's topmost agricultural commodity is soybean (36.6% of total output) that is a major export commodity. Both the countries, despite their strong crop sectors have sufficient livestock based products for domestic consumption (as well as for export).

Countries in South Asia and East Asia Pacific are generally characterized by the dominance of the crop sector in usually rice based agriculture. Indonesia and Sri Lanka with crop sector (CS) contribution of 88.9% and 88.4% respectively, Bangladesh 86.5%, Myanmar 81.6%, Malaysia 77.7%, Thailand 77.3%, Vietnam 74.5%, Philippines 73.3%, Nepal 71.7% are typical examples. Low income countries in Africa such as Madagascar (75.4%), Zambia (71.9%) in Sub-Saharan Africa, and upper middle order country Turkey (67.2%) in Europe and Central Asia are crop sector oriented , so is Greece with a 70.2% crop sector and is a notable departure from the livestock dominated agriculture of the OECD countries.

Commoditywise Agricultural Performance : Crop and Livestock Sectors

Production in the crop sector of 33 representative countries in the year 2010 and per capita availability

We have earlier discussed the general agricultural performance of 51 selected countries. For commodity wise discussion on the crop sector we have reduced the number of countries to 33 keeping the discussion as representative as possible of the current global scenario.

The data presented in Table 5 give the countrywise production figures in million metric tonnes (mmt) of the grains (rice, wheat, maize, soybean etc. the total number of grain crops shown in parenthesis), potatoes, cassava, sugarcane, sugar beet, cotton, oil crops (sunflower, groundnut, rapeseed, cotton seed, sesame, palm oil, olives, coconut oil etc.), miscellaneous commercial crops that yield jute fibre, tobacco, coffee (green), cocoa, tea etc., vegetables including pulses and tomatoes, and total fruits (tropical/temperate). Table 6 shows the overall availability of the aforesaid commodities in kg/person/year obtained by dividing the values in Table 5 by the estimated population of the particular country in the year of production and it would be worthwhile to discuss them together when considered necessary.

Grain crops: China produced 490 mmt of total grains (rice, wheat and maize) closely followed by USA with total 478 mmt (maize, wheat and rice) both far ahead of India producing 201 mmt of grains (rice, wheat), Brazil with 142 mmt of grains (soybeans, maize, wheat, rice), 92 mmt (soybeans, maize, wheat and rice) in Argentina and 85 mmt (rice, maize) in Indonesia. Although all the aforesaid countries are large grain producers, their per capita availability per year of grains (composite) is determined greatly by population size. Thus for China it is 362 kg/person/year against 1544 kg/person/year of USA a value 4.3 times higher than China (Table 5, 6, also see Table 29). It is only 165 kg/person for India less than half of China and only 10.7% of USA. Annual grain availability per capita is 303 kg in Bangladesh, 195 kg in Pakistan better than India but there are countries which are worse off. It is 21 kg in Spain, 40 kg in Cuba. In Cuba, however, per capita availability of 115 kg starchy food from 1.3 mmt of cassava, effectively compensates that shortage besides plentiful availability of fresh vegetables. The grain availability per person in several other countries are as follows : 50 kg in Colombia, 83 kg in Japan and interestingly nil in the Netherlands, obviously those countries

Table 5.

Production of crops in 33 countries in 2010 (production in million metric tons, mmt)

Sl. No	Countries	Grain crops (composite)	No. of grain crops	Potatoes	Cassava	Sugarcane	Sugarbeet	Cotton	Oil Crops	Misc. commercial crops rubber, tobaco, tea, coffee etc	Vegetables including tomatoes	Fruits (composite)
1	Argentina	91.5	4	2. 0	0	29. 0	0	0.23	2.8	0	0.7	5.3
2	Australia	29.4	3	1.3	0	31.5	0	0.39	2.7	0	1.1	2.3
3	Bangladesh	50.3	2	7.9	0	5.3	0	0	0	1.2	2.4	3.45
4	Brazil	141.9	4	0	24.4	719.2	0	0.97	0	3.7	6.9	29.04
5	Cambodia	9.8	3	0	4.2	0	0	0	0.08	0.05	0	0.3
6	Cameroon	2.6	2	0	3. 0	0	0	0.06	0	0.34	0	0.95
7	Canada	49.2	4	4.4	0	0	0	0	11.9	0	5.14	0.43
8	China	490	3	74.8	0	0	0	5.97	15.7	0	240.6	48.5
9	Colombia	2.4	1	2.1	0	20.3	0	0	0.8	0.51	3.8	4.05
10	Cuba	2.4	1	0	0.41	11.3	0	0	0	0.02	2.3	0.95
11	Egypt	11.5	2	3.6	0	15.7	7.8	0	0.61	0	11.4	9.17
12	France	62.3	3	6.6	0	0	31.9	0	6.55	0	0.91	7.56
13	Germany	22.4	3	10. 0	0	0	20.6	0	5.3	0	1.22	2.41
14	India	201	2	36.6	0	278	0	5.7	0	0	77.3	57.8
15	Indonesia	84.8	2	0	23.9	26.5	0	0	50. 0	4.4	1.87	9.3
16	Italy	8.5	2	0	0	0	0	0	3.2	0	7.16	15.23
17	Japan	10.6	1	2.1	0	0	3.1	0	0	0	6	2.44
18	Kenya	0.8	2	0.5	0	5.7	0	0	0	0.4	4.14	1.73
19	Madagascar	5.1	2	0.2	3	3. 0	0	0	0	0.08	1.54	0.75
20	Mexico	27	2	0	0	50.4	0	0	0	0.27	8.42	11
21	Mayanmar	33.2	1	0	0	9.7	0	0	1.36	0	10.6	1.35
22	Netherlands	0		6.8	0	0	5.3	0	0	0	4. 0	0.66
23	Pakistan	33.9	3	3.1	0	49.4	0	1.95	3.7	0	1.7	4.1
24	Philippines	22.2	2	0	2.1	34. 0	0	0	15.5	0.4	4.96	15.6
25	Russian Fed.	42.6	2	21.1	0	0	22.3	0	5.34	0	9.5	1.61
26	South Africa	15.2	3	2.2	0	21. 0	0	0	0.5	0	0.96	4.3
27	Spain	0.9	1	2.3	0	0	0	0	8. 0	0	7.1	7.06
28	Sri Lanka	4.3	1	0	0	0	0	0	2.24	0.42	0.88	0.15
29	Thailand	36.1	2	0	22. 0	68.8	0	0	2.6	3.1	1.26	6.84
30	United Kingdom	19.9	2	5.9	0	0	7.4	3.94	1.9	0	1.93	0.34
31	United States	478	4	18. 0	0	0	0	0	0	0	7.71	20.6
32	Vietnam	40	1	0	8.5	15.9	0	0	0.49	2.1	7.2	6.65
33	Zambia	3	3	0	1.2	4.1	0	0.03	0.23	0.09	0.79	0.08
	WORLD	2429	4	324	229	1685		23.5			386	2787

Table 6.

Per capita availability (kg/person/year) of grains, potatoes, cassava, vegetables and fruits in 33 selected countries in 2010

Sl. No	Countries	Rice	Wheat	Maize	Soybean	others	Total Grains	Potatoes	Cassava	Vegetables	Fruits
1	**Argentina**	29.5	543	557.7	1294.8	342.7	2248	49.1	0	17.2	130.2
2	**Australia**	0	1037.6	0	0	0	1380	61	0	51.6	108
3	**Bangladesh**	297.4	5.4	0	0	0	303	47.6	0	14.4	20.8
4	**Brazil**	57	30.5	283	345.4	0	716	0	123	34.8	146.4
5	**Cambodia**	535.9	0	91.5	10.5	0	638	0	275	39.2	19.6
6	**Cameroon**	0	0	86.7	0	0	133	0	153	431 ?	48.5
7	**Canada**	0	686.4	346.2	128.7	0	1454	130.2	0	152	12.7
8	**China**	145.8	85.2	131.2	0	0	362	55.3	0	177.8	35.8
9	**Colombia**	50.3	0	0	0	0	50	44	50	79.7	84.9
10	**Cuba**	39.8	0	0	0	0	40	0	36	203.5	84.1
11	**Egypt**	54.6	90.4	0	0	0	145	45.9	0	143.9	115.6
12	**France**	0	614.1	225.1	0	161.3	1001	105.8	0	14.6	121.5
13	**Germany**	0	273	0	0	0	450	121.5	0	14.8	91.9
14	**India**	99.1	66.3	0	0	0	165	30.1	0	63.5	47.5
15	**Indonesia**	278	0	76.9	0	0	355	0	100	7.8	38.9
16	**Italy**	27.8	117.1	0	0	0	145	0	0	121.6	258.6
17	**Japan**	83.3	0	0	0	0	83	16.3	0	47.1	19.2
18	**Kenya**	0	12.6	79.6	0	0	92	11.1	0	102.2	427
19	**Madagascar**	223.4	0	19.4	0	0	243	10.6	142	72.6	35.4
20	**Mexico**	0	33.5	212.6	0	0	246	0	0	76.8	100.4
21	**Myanmar**	665.4	0	0	0	0	665	0	0	198.5	27.1
22	**Netherlands**	0	0	0	0	0	0	415	0	242.7	39.7
23	**Pakistan**	41.6	134	19.2	0	0	195	18.1	0	9.8	23.5
24	**Philippines**	179.3	0	68.9	0	0	239	0	23	53.6	168.2
25	**Russian Fed.**	7.6	295.6	0	0	0	303	150.6	0	67.7	11.4
26	**South Africa**	0	30.5	266.4	11.6	0	309	44.6	0	19.6	87.6
27	**Spain**	20.8	0	0	0	0	21	51.1	0	159.2	158.2
28	**Sri Lanka**	220.5	0	0	0	0	221	0	0	48.8	7.6
29	**Thailand**	486.9	0	68.6	0	0	556	0	339	19.4	83.6
30	**United Kingdom**	0	240.2	0	0	85.3	326	95.5	0	31.4	5.6
31	**United States**	35.6	194.2	1021.5	292.8	0	1544	58.2	0	66.7	66.3
32	**Vietnam**	441	0	0	0	0	441	0	94	74.2	73.4
33	**Zambia**	4.1	13.7	221.9	0	0	240	0	91	44.6	6.6
	WORLD	**97.6**	**94.6**	**122.7**	**38**		**353**	**47.1**		**56.1**	**40.5**

depend on imports of grains from other countries notably from Latin America for domestic need for food and particularly as feed for livestock.

Potato etc: As with grains China is the largest producer of potatoes, but because of its huge population per capita availability is moderate. Potato is the most important carbohydrate-rich (starchy) crop in the Netherlands and in the grain deficient country per capita availability of potato is the highest at 415 kg/year. A good number of countries such as Spain and Italy do not grow potatoes and in many warm humid countries cassava, yams and plantains serve as effective energy yielding crops especially in Latin America, Caribbean and South Asian, East Asia Pacific and African countries. In Cameroon, plantain is the most important commodity contributing to nearly 15% of the countries agricultural output. Although India produces 37 million tonnes of potato each year (second to China's 75 mmt / year), its per capita availability is just 30 kg per person because potato is used as a vegetable rather than a staple food as in European countries like Netherlands (415 kg/person), Germany(122 kg/person), France (106 kg/ person), UK (96 kg/person), Russia (151 kg/ person), Canada (130 kg/person) etc.(Table 6).

Oil yielding crops : Oil yielding crops are of diverse kinds – they include rapeseed, sesame, sunflower, groundnut, linseed, coconut, oil palm, olives and also cotton seed oil, rice bran oil as edible oils and nonedible oils such as linseed oil, castor oil, turpentine oil mostly for medicinal and industrial uses. We shall discuss only major edible oils hereunder. China produces 15.7 mmt groundnuts (valued at $6.9 billion) and the highest quantity of cotton seed for oil extraction. However, in terms of oil revenue Indonesia produces $9.4 billion worth of palm oil (21.5 mmt) followed by Malaysia's 17 mmt of palm oil valued at $7.4 billion (it is Malaysia's topmost agricultural output) and major export commodity of both the countries. Canadian rapeseed (production 11.9 mmt valued at $3.3 billion) is also a very important export commodity, the same is true for 15.5 mmt coconut oil of Philippines (valued at 1.7 billion). The topmost agricultural commodity of Spain is olives (23.7% of the countries agricultural output, 8.0 mmt, valued at $6.4 billion) and of Greece (26.6% of country's produce, 1.8 mmt valued at $1.4 billion) are important revenue earners for the respective countries. India is a country that is chronically oil deficit and depends on supply of rapeseed oil from Canada and palm oil from Malaysia.

Sugar crops : The demand for sugar is met either by sucrose from sugarcane or sugar beet popularly known as cane sugar and beet sugar respectively or simply sugar (both). Sugarcane is a tropical crop and sugar beet is a temperate crop, as such tropical and subtropical countries grow sugarcane whereas temperate countries grow sugar beet but several subtropical countries can grow sugar beet such as Egypt in winter months on a commercial scale. Brazil is the World's largest sugarcane producer (the country's topmost commodity) and its commercially viable cane sugar based ethanol mixed with petrol serves as an effective transport fuel. India is the second largest producer of the cane sugar but because of its large population, the availability per capita like all other commodities is low. Thailand, Pakistan, Mexico, Philippines and Australia are also important cane sugar producers. France (32 mmt), Russian Fed. (22 mmt), Germany (21 mmt) on the other hand produce sugar beet to meet much of their domestic demand (Table 5, 6).

Fibre crops : In cotton production China (6 mmt), India (5.7 mmt), USA (3.9 mmt), Pakistan (2.0 mmt) and Brazil (1 mmt) are the leading countries (Table 5). Jute a bast fibre is produced in Bangladesh and India, the natural fibre has a good export market as well. Bangladesh produces 1.2 mmt valued at $340 million and exports a part of that; for India jute is not of sufficient value for inclusion within a maximum of 20 items in FAO database (also many other items as would the case of countries with a wide range of agricultural products), it is therefore not included in the present discussion on India along with miscellaneous commercial crops that include natural rubber, tobacco, beverages such as tea, coffee, cocoa, etc.

Vegetables : So far as vegetables are concerned China's overall contribution (including tomato) is exceptionally high, a staggering 241 mmt (per capita availability 179 kg/year) about three times that of India (77 mmt, per capita availability 64 kg/year),that is second in vegetable production (Table 5, 6). However, Netherlands, a small country (where livestock contribution is very high and one that does not produce grains, grows 4 mmt of vegetables and per capita vegetable availability is the highest (243 kg/year). Although we have noted the high figure of 431 kg plantains/capita for Cameroon, the same is actually the major energy food of the country while it is in India and many other countries treated as a fruit vegetable. Compared to its size Cuba grows sufficient quantity of vegetables so that per capita availability is as high as 204 kg/year. Per capita availability of vegetables is also high in Myanmar (199 kg/ year), Spain (158 kg/year), Canada (152 kg/ year), Egypt (141 kg/year), Italy (122 kg/year), Kenya (102 kg/year) and so on. It is very low in Indonesia (7.8 kg/year), Pakistan (10 kg/year), Bangladesh (14.4 kg/year), France (14.6 kg/ year), Germany (14.8 kg/year) etc.

Fruits : India is the top fruit producing country now (58 mmt, per capita availability only 48 kg/year). China is the second big producer with 49 mmt, per capita availability of 36 kg /year (Table 5, 6). The next country in total fruit production is Brazil (29 mmt, 146 kg per capita availability/year). The other 7 countries in the list of top 10 countries are USA (20 mmt, availability 66 kg/person/year), Philippines (16 mmt, 168 kg/person/year), Italy (15 mmt, 259 kg/person/year), Indonesia (9 mmt, 39 kg/person/year), Egypt (9 mmt 116 kg/ person/year), Spain (7 mmt,158 kg /person/ year). Countries with very low availability of fruits include very surprisingly UK (production 0.34 mmt, per capita availability 5.6 kg/year), Zambia (0.08 mmt, 6.6 kg/year), Sri Lanka (0.15 mmt, 7.6 kg/year), Russian Fed. (1.6 mmt, 11.4 kg /year), Canada (0.43 mmt, 12.7 kg/year), Japan (2.44 mmt, 19.2 kg/year), Cambodia (0.3 mmt ,19.6 kg/year), Bangladesh (3.5 mmt, 20.8 kg/year), Pakistan (4.1 mmt, 23.5 kg/year) etc. As surplus product from many countries are exported, the lack of availability in deficit food commodities would be compensated by imports, as such, high income countries would not suffer because of low domestic production but for low income countries there would be a persistent problem of inadequacy of food and other commodities.

Other commercial crops : Natural rubber is in great demand and the rubber producing developing countries export the latex to the developed industrial countries. Thailand is the top producer (3.1 mmt valued at $3.5 billion), followed by Indonesia (2.8 mmt, $3.2 billion), Malaysia (0.86 mmt,$982 million), Vietnam (0.75 mmt, $863 million), Philippines (0.40 mmt, $452 million), Sri Lanka (0.14 mmt, $159 million), Cameroon (0.05 mmt, $63 million), Cambodia (0.04 mmt, $43 million) and few others (Table 5, 6).

Brazil is the largest producer of tobacco (unmanufactured) with 0.78 mmt of production valued at $1.24 billion. The other producers are Zambia (0.09 mmt,$143 million), Cuba (0.02

mmt, $33 million), Cambodia (0.015 mmt, $23 million) etc. In production of coffee also, Brazil dominates with 2.87 mmt, valued at $3.1 billion followed by Vietnam (1.11 mmt, $1.2 billion), Indonesia (0.80 mmt, $861 million), Colombia (0.51 mmt, $552 million), Mexico (0.25 mmt,$273 million), Madagascar (0.08 mmt, $87 millions) and Cameroon (0.07 mmt, $72 million).

Indonesia is the largest cocoa (beans) producing country (0.8 mmt, $841 million) besides Cameroon (0.26 mmt, $274 million), Kenya is a important exporter of tea (0.4 mmt, $424 million), followed by Sri Lanka (0.28 mmt, $300 million) and Vietnam (0.20 mmt, $211 million) and as with the most commercial crops, the export to the consuming developed countries in particular boosts the respective national economies.

Production and availability of livestock products in the 33 countries

In Table 7 the indigenous production of livestock commodities in 33 countries for the year 2010 are presented in million metric tonnes (mmt) and the per capita availability of the product is given in kg/person/year. As with the crop sector it needs to be pointed out that the availability is not synonymous with consumption as many of the countries are net exporters while many others import products to meet domestic demands if their economic conditions so permit. We have used the terms cow milk equivalent (CME) , hen egg equivalent for eggs, mutton equivalent, chicken equivalent for meat because of the fact that other than cow milk (CM), milk from various other sources such as buffalo, goat, sheep, camel, horse etc. are used in some countries, as such equivalence based on price (in $) of cow milk has been worked out for the sake of uniformity (buffalo milk is 1.314 times costlier and as such multiplied by a factor of 1.314 for cow milk equivalence) Similarly besides hen eggs, other bird eggs such as duck eggs are costlier and so multiplied by 3.48 for hen equivalent value. Mutton is the costliest meat ($2723/mt), followed by beef ($2701/mt), pork ($1537/mt) and chicken meat ($1424/mt); equivalence based on $value per tonne has been worked out as mutton equivalent and chicken equivalent figures.

Milk production and per capita availability : Milk production (total of cow milk and buffalo milk) is now highest in India (130 mmt CME) followed in order by the following nine countries, USA (88 mmt), Pakistan (42 mmt), Russian Fed. (32 mmt), Brazil (32 mmt), China (30 mmt), UK (14 mmt), Netherlands (12 mmt), Italy (11 mmt) and Argentina (11 mmt). In terms of availability per person per year the Netherlands is at the top with a very high value of 705 kg followed by Australia (423 kg), France (386 kg), Germany (340 kg), USA (279 kg), Argentina (258 kg), Canada (244 kg), Pakistan (240 kg), UK (233 kg), and Russian Fed. (227 kg). India the top producer is lowly placed at 107 kg (attributed to a large population) although there are countries like Cambodia, Vietnam, Philippines, Indonesia that are not traditionally milk users. Availability of milk in China is only 22 kg per person, Zambia (7 kg), Sri Lanka (8 kg), Thailand (13 kg), Bangladesh (21 kg) and Myanmar (23 kg) are poor in milk availability per person (Table 7).

Egg production and per capita availability : In egg production (Table 7), China (38.4 mmt) is far ahead of other countries, 7 times higher than USA (5.4 mmt) and over 11 times that of India (3.4 mmt). Among the top 10, the others are Japan (2.5 mmt), Mexico (2.4 mmt), Russian Fed. (2.3 mmt), Indonesia (2 mmt), Thailand (2 mmt), Brazil (2 mmt) and France (1 mmt). In terms of availability per person per year the Netherlands is in the first place (38.2 kg per person per year; approximately 13.3 eggs per kg i.e. 510 eggs each of 70 gram weight 'A' size hen eggs). The others among the top ten are USA (402 eggs), China (378 eggs), Australia (293 eggs), Mexico (290 eggs), Japan (263 eggs), Spain (251 eggs), Russian fed. (215 eggs), France (210 eggs). Eggs do not feature in the list of top 20 commodities in Cameroon, Egypt and Madagascar; its availability is 21 eggs per person per year in Sri Lanka, 27 in Kenya, 30 in Cambodia, 37 in India, 43 in Pakistan, 48 in Vietnam and 49 in Bangladesh.

Meat production and per capita availability : Meat production (composite) is highest (70 mmt) in China (Table 7) and pig meat is the country's topmost agricultural produce (over $79 billion in 2010), USA is in the second position (40 mmt), the rest of the top 10 include Brazil (21 mmt), Russian Fed. (6.6 mmt), Germany (6.6 mmt), France (6.0 mmt), Mexico (5.8 mmt), Canada (5.2 mmt), Spain (5.1 mmt) and India (4.9 mmt). Regarding availability of meat (composite), Netherlands is at the top (206 kg/person/yr) followed by Australia (195 kg), Canada (155 kg), USA (128 kg), Spain (115 kg), Argentina (111 kg), Brazil (106 kg), France (96 kg), Germany (80 kg) and Italy (65 kg). The aforesaid estimates would be lower if converted to mutton equivalent values and higher for chicken equivalent estimates, the exact values depending on the relative proportion of sheep meat, cattle meat, pig meat, chicken meat in the total (composite) meat produced in a country (mutton equivalent values multiplied by 1.9 will give chicken equivalent values; as such the relative position of a country would remain unchanged in respect of mutton and chicken equivalent values but would differ from composite meat estimation (Table 7). Thus in terms of mutton/chicken equivalent values the top position in last 10 countries regarding availability goes to Australia (168 kg/321 kg) followed by the Netherlands (121 kg/231 kg), Canada (106 kg/202 kg), Argentina (88 kg/169 kg), USA (85 kg/161 kg), Brazil (73 kg/140 kg), Spain (70 kg/133 kg), France (65 kg/124 kg), Germany (52 kg/99 kg) and Italy (43 kg/82 kg). For India it is quite insignificant (3 kg/6 kg) attributable to a vast population of 1.2 billion, the values for its neighbours are same for Bangladesh but higher for Pakistan (13 kg as mutton equivalent or 25 kg as chicken equivalent/person/year).

Valuewise distribution of 20 commodities in 4 groups: Distribution (share) as percentage of total output value in US dollars

We have discussed the distribution of agricultural produce as top 5 products of 51 countries. As FAO data sheet for different countries include maximum of 20 commodities (it may be less in small countries for example data on Bahamas include only 19 commodities) and as the order of arrangement is valuewise, it would be natural that the share of items lower in the list would be lower. It would also be of interest to see the trend for different countries in terms of emphasis on production of specific commodities. We therefore grouped the commodities into 4 groups each with 5 agricultural products as shown in Table 8. The 33 countries selected for the purpose show interesting differences and we find Cambodia, Bangladesh, Netherlands have the major portion of their agriculture output confined to 5 commodities of the first group as 86.8, 82.6 and 78.6% respectively, while it is as low as 46.7% in Cameroon, 47.1% in Egypt, 54% each in China and Cuba. It is not related to size of the agricultural economy. While there is a definite progressive decline in the share of the second, third and fourth groups, there are considerable quantitative differences in the aforesaid trend. Thus in group II, the range is 7.2% to 23.6%, in the group III 4.9% to 16.3% and 2.2% to 9.9%

in group IV; higher share in last groups would reflect greater emphasis on product diversity. Nevertheless the summation of first two groups shows that 75 to 92% of the total agricultural outputs of countries are covered by 10 agricultural commodities. It is interesting to note that the distribution of world's top 20 commodities (last row, Table 8) appear to be gradual and reflects a broad based agricultural scenario, obviously because of the summation effect on mutually compensating trends of constituent countries. Putting too much emphasis on small number of products may often be counterproductive and may increase dependence on imports that would be difficult for low income countries. Even high income countries such as grain deficit livestock producers like the Netherlands, may also run the risk of nonsustainability in case of unavailability of feed grains from other countries because of various reasons.

Mean total output, output and income per ha and relative crop and livestock shares for selected 33 countries

We have so far discussed agricultural performance for the latest available annual data (year 2010) from the FAOSTAT database but discussion with several agricultural researchers and noted scientists indicated that it would be better if mean data of a longer period are also considered for the purpose and we naturally agreed despite the fact that estimations and calculations would be multiplied manifold. We reduced the number of representative countries to 33 from 51 and used half decadal and decadal means (for major agricultural economies) along with the respective standard deviations. It needs to be pointed out that SD values for CS% and LS% for any country would be the same for obvious mathematical reason, but because of the difference in means of CS and LS of a particular country, the coefficient of variation (CV) would be different. As would be seen in Table 9 the broad observations on major issues have not shown any noticeable difference in the trends and patterns of parameters in quantitative terms; in many countries there has been a 1-2% increase in production. For example the total output of India in 2010 is $164,770 million (Table 4) the mean of 5 years (2006-2010) is $157,492; the difference is around 1% annually.

We have earlier discussed the data on total output per hectare and output per capita and the relative share of crop and livestock sectors in the 51 selected countries (Table 4) which are close to the mean values for the same countries here as well. But actual profit in terms of net income per hectare, after deducting the cost of cultivation, needs to be discussed critically. The income estimations in Table 9 are based on the same assumptions as that of Cline (2007); the ratios of agricultural income and net output according to him has been as follows Africa 0.78, India and SE Asia 0.67, Asia and Middle East 0.60, Latin America 0.50, EU, Japan, Australia and New Zealand 0.45, USA 0.41 (Canada would be the same). Consequently total output/ha or output/capita need to be multiplied by the respective ratios (0.67 for India, 0.41 for USA and so on) for corresponding net income values. As such, net income /ha is highest in Egypt ($3210/ha), while it is $2614/ha in the Netherlands which has the highest output/ha ($5809/ha) that is substantially higher than Egypt ($4116/ha) because cost of production in the former is much higher. Incidentally farm area of Egypt is only 3.9% of its total land area compared to 61.6% farm area of Netherlands. Therefore total agricultural income of the Netherlands is much higher than Egypt. Income per hectare is quite high in Vietnam ($1732/ha), Japan ($1553/ha) and Bangladesh ($1431/ha), Philippines ($1114/ha) etc. It is lowest in Australia ($21/ha), Russian Fed. ($27/ha),

Table 7.

Production and availability of livestock commodities in 33 countries in 2010

Sl. No	Countries	Milk mmt	(CM/CME) kg/person/ year	Egg (hen/hen equivalent)			Meat (cattle,pig,chicken etc)			
				mmt	kg/capita/ year	Number of eggs/year	Composite		Mutton equivalent/ kg/year	Chicken equivalent/ kg/year
							mmt	kg/year/ capita		
1	**Argentina**	10.5	258	0.51	12.4	166	4.5	111	88	169
2	**Australia**	9	423	0.17	22	293	4.17	195	168	32.1
3	**Bangladesh**	3.5	21	0.43	3.7	49	0.59	3.6	2.9	5.6
4	**Brazil**	31.7	160	1.95	9.9	132	21.01	106	73	140
5	**Cambodia**	0	0	0.034	2.24	30	0.59	38	23	45
6	**Cameroon**	0.18	9	0	0	0	0.29	15	12	22
7	**Canada**	8.2	244	0.43	12.7	169	5.24	155	106	202
8	**China**	30.04	22	38.35	28.3	378	69.69	52	31	59
9	**Colombia**	7.5	157	0.51	10.7	143	2.13	45	33	62
10	**Cuba**	0.63	56	0.11	9.5	126	0.27	24	16	31
11	**Egypt**	6.4	81	0	0	0	1.42	18	14	26
12	**France**	24	386	0.95	15.2	203	5.96	96	65	124
13	**Germany**	28	340	0.8	9.7	129	6.58	80	52	99
14	**India**	130.1	107	3.41	2.8	37	4.85	4	3	5.9
15	**Indonesia**	0	0	2.03	8.5	113	2.54	11	6	12
16	**Italy**	10.5	178	0.74	12.5	167	3.86	65	43	82
17	**Japan**	7.7	61	2.52	19.8	263	3.2	25	15	29
18	**Kenya**	5.2	127	0.08	2	27	0.55	14	13	26
19	**Madagascar**	0.7	33	0	0	0	0.25	12	10	19
20	**Mexico**	10.7	97	2.38	22	290	5.8	53	37	70
21	**Myanmar**	1.14	23	0.28	5.6	75	1.52	30	18	34

Contd.

Table 7. Contd.

Sl. No	Countries	Milk mmt	(CM/CME) kg/person/ year	Egg (hen/hen equivalent)			Meat (cattle,pig,chicken etc)			
				mmt	kg/capita/ year	Number of eggs/year	Composite		Mutton equivalent/ kg/year	Chicken equivalent/ kg/year
							mmt	kg/year/ capita		
22	**Netherlands**	11.63	705	0.63	38.2	510	3.41	206	121	231
23	**Pakistan**	41.75	240	0.56	3.2	43	2.64	15	13	25
24	**Philippines**	0	0	0.66	7.1	95	2.7	29	18	34
25	**Russian Fed.**	31.9	227	2.26	16.1	215	6.64	47	32	61
26	**South Africa**	3.54	72	0.46	9.45	126	3.13	64	46	87
27	**Spain**	6.36	143	0.84	18.83	251	5.13	115	70	133
28	**Sri Lanka**	0.16	8.3	0.03	1.54	21	0.12	6	4	7
29	**Thailand**	0.85	13.1	1.96	30.2	402	2.52	39	23	44
30	**United Kingdom**	14.32	233	0.59	9.67	129	3.35	55	38	72
31	**United States**	87.46	279	5.41	17.3	230	40.03	128	85	161
32	**Vietnam**	0	0	0.33	3.59	48	3.86	43	26	49
33	**Zambia**	0.09	7	0.05	3.93	52	0.16	13	10	20
	WORLD	**721**	**105**	**63.6**	**9.24**	**123**	**265.2**	**39**	**25**	**47**

Table 8.

Valuewise distribution of 20 commodities in four groups(%) in 33 selected countries in the year 2010

Sl. No	Countries	Group I (1-5)	Group II (6-10)	Sum of Gr I & II (1-10)	Group III (11-15)	Group IV (16-20)	Contribution (%) of the topmost commodity (first item) to total output	
1	**Argentina**	76.6	15. 0	91.6	4.9	3.5	Soybean	36.6
2	**Australia**	70.5	18.5	89. 0	8.2	2.8	Cattle meat	29.9
3	**Bangladesh**	82.6	8.9	91.5	4.9	3.6	Rice	66.4
4	**Brazil**	72.6	15.3	87.9	7.3	4.8	Sugarcane	20.3
5	**Cambodia**	86.8	7.3	94.1	3.7	2.2	Rice	61.5
6	**Cameroon**	46.2	28.5	74.7	16.3	9. 0	Plantain	14.8
7	**Canada**	70.9	19.2	90.1	6.5	3.4	Cattle meat	18.1
8	**China**	54.1	21.8	75.9	14.2	9.9	Pig meat	23.1
9	**Colombia**	63	20.2	83.2	11.2	5.6	Cattle meat	21.1
10	**Cuba**	54.1	24.3	78.4	13.6	7.9	Sugarcane	15.9
11	**Egypt**	47.5	26.4	73.9	15.8	9.9	Tomatoes	20.1
12	**France**	67.3	18. 0	85.3	10.1	4.4	Cow milk	20.9
13	**Germany**	75.5	16.1	91.6	6.2	2.2	Cow milk	29.2
14	**India**	57.4	22.9	80.3	11. 0	8.6	Rice	19.5
15	**Indonesia**	69.3	15.7	85. 0	8.6	6.4	Rice	35.2
16	**Italy**	60.4	23.6	84. 0	9.5	7.1	Grapes	17.8
17	**Japan**	71. 0	17.8	88.8	7.3	3.9	Rice	18.3
18	**Kenya**	68.7	17.2	85.9	8.5	5.7	Cow milk	27.3
19	**Madagascar**	73.6	13.1	86.7	8.2	5.2	Rice	39.4
20	**Mexico**	58.5	22.7	81.2	12.8	6 . 0	Cattle meat	19.1
21	**Myanmar**	73.6	13.2	86.8	8.3	4.8	Rice	49.8
22	**Netherlands**	78.6	13.7	92.3	5. 0	2.7	Cow milk	28.5
23	**Pakistan**	62.8	23.1	85.9	9.1	5.1	Buffalo milk	26. 0
24	**Philippines**	64.1	21.7	85.8	9.9	4.2	Rice	22.2
25	**Russian Fed.**	69.8	21. 0	90.8	5.7	3.6	Cow milk	25.1
26	**South Africa**	65.7	19. 0	84.7	9.7	5.8	Cattle meat	21.9
27	**Spain**	69.3	17.4	86.7	8.1	5.3	Olives	23.7
28	**Sri Lanka**	75.9	12.9	88.8	6.9	4.3	Rice	44. 0
29	**Thailand**	67.6	20.7	88.3	7.9	3.4	Rice	30.4
30	**United Kingdom**	70.6	20.6	91.2	5.7	2.9	Cow milk	28.8
31	**United States**	67.2	19.8	87. 0	8.7	4.3	Cattle meat	15.5
32	**Vietnam**	73.2	15.8	89. 0	7. 0	4. 0	Rice	41.6
33	**Zambia**	63.9	19.9	83.8	10.5	5.7	Maize	26.1
	WORLD	**55.2**	**20.9**	**76.1**	**14.6**	**9.3**	**Cow milk**	**12.2**

Table 9.

Mean total output, output per hectare, income per hectare and relative share of crop sector (CS) and livestock sector (LS) for each of the 33 selected countries (all values are means of 5 years covering the period 2006 - 2010) :
Mean of 5 years (2006-10) for selected 33 countries

Countries	Output/ha ($) Mean ± SD	Income /ha ($) Mean ± SD	Mean CS output million ($)	CS percent Mean ± SD	Mean LS output Million ($)	LS percent Mean ± SD	Mean total output Millon $
Argentina	240.2± 16.7	120±8	21981	60.3±4.4	14471	39.7±4.4	36452±2534
Australia	46.5±1.04	21±1	7627	36.7±2.0	13154	63.3±2.0	20781±465
Bangladesh	2135.6±146.0	1431±98	16063	86.2±2.0	2572	13.8±0.3	18635±1273
Brazil	355.7±12.3	178±6	59922	54.7±2.2	49625	45.3±2.2	109547±3787
Cambodia	672.0±66.0	450±45	2708	86.8±2.2	412	13.2±2.2	3120±309
Cameroon	427.4±17.6	260±14	2901	84.1±1.4	549	15.9±1.4	3450±142
Canada	357.7±13.3	147±5	10700	45.6±3.1	12764	54.4±3.1	23464±872
China	940.4±39.1	564±24	184541	55.7±0.9	146772	44.3±0.9	331313±13769
Colombia	266.2±10.4	133±5	5662	45.8±1.9	6700	54.2±1.9	12362±483
Cuba	453.1±17.4	227±9	1501	67.8±3.1	713	32.2±3.1	2214±85
Egypt	4115.5±16.9	3210±13	11188	70.3±1.7	4727	29.7±1.7	15915±65
France	1152.5±10.2	519±5	15155	44.2±1.4	9132	55.8±1.4	34287±303
Germany	1655.3±61.4	745±28	8750	29.2±1.1	21215	70.8±1.1	29965±1111
India	896.2±37.0	600±25	108512	68.9±1.2	48980	31.1±1.2	157492±6502
Indonesia	1142.9±77.1	766±52	42008	89.0±0.4	5192	11.0±0.4	47200±3185
Italy	1491.5±19.4	671±9	14736	58.1±0.9	10628	41.9±0.9	25364±330
Japan	3450.0±43.0	1553±19	6566	40.0±0.8	9830	60.0±0.8	16396±204
Kenya	337.6±18.9	263±15	2620	48.7±1.5	2759	51.3±1.5	5379±302
Madagascar	130.5±10.9	102±9	2189	75.6±0.6	706	24.4±0.6	2895±241
Mexico	187.7±2.8	94±1	11540	42.3±1.2	15742	57.7±1.2	27282±407

Contd.

Table 9. Contd.

Countries	Output/ha ($) Mean ± SD	Income /ha ($) Mean ± SD	Mean CS output million ($)	CS percent Mean ± SD	Mean LS output Million ($)	LS percent Mean ± SD	Mean total output Millon $
Myanmar	1403.0±69.3	940±46	12910	82.3±0.5	2777	17.7±0.5	15687±775
Netherlands	5809.2±213.3	2614±96	3082	25.4±0.4	9051	74.6±0.4	12133±444
Pakistan	1288.6±47.1	863±32	13920	44.0±1.3	17716	56.0±1.3	31636±1156
Philippines	1662.5±51.7	1114±35	13411	73.2±0.6	4910	26.8±0.6	18321±570
Russian Fed.	48.3±1.6	27±1	15138	41.5±3.5	21339	58.5±3.5	36477±1209
South Africa	192.0±15.2	150±12	4721	41.3±1.5	6711	58.7±1.5	11432±904
Spain	740.0±18.0	333±8	15177	57.7±1.6	11127	42.3±1.6	26304±640
Sri Lanka	1131.5±66.6	758±45	2141	87.9±0.5	295	12.1±0.5	2436±143
Thailand	1315.9±50.0	882±34	20419	79.0±1.0	5428	21.0±1.0	25847±982
United Kingdom	905.6±14.5	408±7	4180	27.2±1.7	11188	72.8±1.7	15368±246
United States	479.6±14.5	197±6	86594	45.6±1.2	103305	54.4±1.2	189899±5739
Vietnam	2584.4±117.1	1732±78	18342	74.5±1.2	5984	24.6±1.2	24326±1102
Zambia	78.7±10.2	61±8	819	68.0±2.6	385	32.0±2.6	1204±158

progressively rising in Zambia ($61/ha), Mexico ($94/ha), Madagascar ($102/ha), Argentina ($120/ha) etc. In India income per hectare is $600, much lower than Bangladesh (less than half) but much higher than the USA ($197/ha). We may point out here that in and after 2008, the year of global financial crisis, the cost of cultivation has gone up in most countries rather disproportionately to the producer's price of agricultural commodities and current net income in many countries could be lower than manifested in the data estimated on the basis of Cline's observations in 2007.

Indian Production Scenario in the First Decade of the 21st Century

The full decadal (2001-2010) along with first half-decadal (2001-2005) and second half-decadal (2006- 2010) average annual production of major crop sector and livestock sector commodities and their per capita availability have been broadly summarized in Table 10 for an assessment of the trend of the agricultural production vis-a-vis significant population growth in the country. In the crop sector rice is most important; in the first half of the decade the annual production was 129 mmt, in the second half decade production went up to 137 mmt but the per capita availability went down from 122 kg/year to 118 kg /year. With most other commodities both production and per capita availability per year showed modest to good increases except for wheat in which there has been no change in per capita availability per year, despite an increase in production the same was nullified by an equal increase in population.

In the livestock sector, milk production (cow milk equivalent, CME) has been quite satisfactory and the per capita availability in the second half-decadal period went up to 103 kg/ year from 90 kg/capita /year in the first decadal half. Egg production in the first decadal half was 2.34 mmt/year (availability 2.2 kg/capita/ year) while it went up to 3.12 mmt/year (availability 2.7 kg/capita/year) in the second half (2006-2010).

Total meat production (composite) consisting of cattle, chicken and buffalo meat showed minor changes with very little change in availability per capita. When meat production (and availability) is changed to chicken equivalent values (based on price per tonne in dollars), a very small increase in production and availability has been recorded (5.4 mmt with availability at 5.1 kg per capita per year in the first half against 6.6 mmt per year and 5.7 kg availability per capita per year in the second half decade). Consumption of meat in a predominantly vegetarian country is indeed insignificant when compared to the basically meat oriented food habits in the western countries. Beside socio-religious issues ,the affordability of low income group of people in south and south east Asia Pacific region is an important reason for the reduced emphasis on meat and other livestock products that are far more expensive than conventional rice based vegetarian diets. Bangladesh, Sri Lanka, Myanmar, Cambodia, Malaysia, Indonesia are typical examples of such countries. The data on world production scenario (Tables 11, 12) show that globally during (2006-10) on an average 38 kg of meat (composite) were available per person per year (the availability would have been much higher if the above noted countries were excluded from estimations).

Global Agricultural Production Scenario

World agricultural production derived from the summation of produce in million metric tonne (mmt) of all countries are presented in Table 11 for the full decade (2001-2010) of the century and the first half of the decade (2001-2005) and second half of the decade (2006-2010), in the same way as in case of India (Table 10).

Table 10.

Indian production scenario in the first decade of the 21st century and in the first half (2001-05) and second half (2006-10) of the decade along with per capita availability

Production in million metric tonnes(mmt) : Availability in kilogram/ capita / year in parenthesis

Agricultural products	Full decade 2001-10		First half 2001-05		Second half 2006-10	
Crop Sector	mmt/yr	(kg/capita /yr)	mmt/yr	(kg/capita /yr)	mmt/yr	(kg/capita /yr)
Rice	133.0 ± 22.0	(119)	128.6±11.70	(122)	137.4±9.8	(118)
Wheat	73.4 ± 5.0	(66)	69.7±2.40	(66)	77.0±4.2	(66)
Sugarcane	289.9 ± 37.4	(260)	270.3±28.7	(25.5)	309.5±34.7	(265)
Cotton lint	3.33 ± 1.23	(3.0)	2.29±0.63	(2.16)	4.36±0.70	(3.73)
Soybean	8.97 ± 1.33	(8.1)	7.66±0.58	(7.24)	9.96±0.75	(8.52)
Millets	12.2 ± 1.70	(11)	12.70±1.90	(12)	-	
Vegetables (incl. onion)	42.1±8.72	(38)	36.1±7.09	(34)	47.2±3.65	(40)
Potatoes	29.0±4.70	(26)	25.3±2.59	(24)	32.7±3.20	(28)
Tomatoes	9.26±1.56	(8.3)	7.86±0.57	(7.4)	10.66±0.80	(9.1)
Pulses	6.25±2.53	(5.6)	4.19±1.31	(4.0)	7.82±2.64	(6.7)
Fresh Fruits (incl. banana, mangoes etc)	39.0±8.93	(35)	31.9±2.61	(30)	46.1±7.11	(39)
Livestock Sector						
Milk,CME (including buffalo milk)	108.0±13.3	(97)	95.7±3.1	(90.4)	120.3±6.5	(103)
Egg (hen equivalent)	2.73±0.44	(2.45) ≡ 32.7 eggs	2.34±0.17	(2.21) ≡ 29.5 eggs	3.12±0.22	(2.67) ≡ 35.6 eggs
Meat						
Cattle	1.003 ± 0.045	(0.90)	0.964 ± 0.01	(0.90)	1.042±0.03	(0.89)
Chicken	1.788±0.40	(1.61)	1.090± 0.00	(1.03)	1.963±0.23	(1.68)
Buffalo	1.372±0.066	(1.23)	1.314± 0.033	(1.24)	1.430±0.03	(1.22)
Pig	–		–		–	
Total Meat (Composite)	4.163±1.03	(3.74)	3.368±0.420	(3.18)	4.435±0.870	(3.79)
Mutton Equivalent	3.288±0.5	(2.95)	2.826±0.210	(2.67)	3.476±0.481	(2.97)
Chicken Equivalent	6.279±1.111	(5.64)	5.398±0.390	(5.10)	6.638±0.91	(5.68)
Median population (millions)	1113.9		1058.3		1169.5	

Table 11.

World agricultural production scenario in the first decade of the 21st century (2001- 2010) and in the first half (2001 - 2005) and second half (2006 - 2010) of the decade along per capita availability [Production in million metric tonnes (mmt) and per capita availability in kg per year]

Crop sector products	Full decade (2001-10)		First half (2001-05)		Second half (2006-10)	
	mmt	(kg/capita /yr)	mmt	(kg/capita /yr)	mmt	(kg/capita /yr)
Rice	634 ± 41	(97.8)	600 ± 21	(95.7)	669 ± 18	(100)
Wheat	622 ± 41	(96)	597 ± 29	(95.2)	647 ± 35	(96.7)
Soybean	213 ± 24	(32.9)	194 ± 14	(30.9)	232 ± 16	(34.7)
Maize	729 ± 84	(112.5)	661 ± 50	(105.4)	779 ± 49	(116.4)
Potatoes	322 ± 9	(48.8	320 ± 9	(51)	333 ± 9	(49.8)
Vegetables	239 ± 8	(36.9)	231 ± 4	(36.8)	246 ± 3	(36.8)
Tomatoes	131 ± 13	(20.2)	120 ± 8	(19.1)	142 ± 8	(21.2)
Grapes	65.9 ± 2.4	(10.2)	64.5 ± 2.6	(10.3)	67.3 ± 1.0	(10.1)
Apples	63.5 ± 49	(9.8)	59.4 ± 2.7	(9.5)	67.7 ± 2.4	(10.1)
Bananas	82.4 ± 11.9	(12.7)	71.7 ± 4.6	(11.4)	93.0 ± 6.0	(13.9)
Mangoes etc	38.7	(6)	–	–	38.7	(6.8)
Sugarcane	1477 ± 169	(228)	1329 ± 36	(212)	1626 ± 108	(243)
Cotton lint	22.5 ± 2.2	(3.5)	21.7 ± 2.4	(3.46)	23.4 ± 1.5	(3.5)
Cassava	209 ± 19.5	(32.3)	193 ± 9	(30.8)	229 ± 4	(34.2)
Livestock products						
Cow milk	550 ± 33	(88.9)	520 ± 16	(82.8)	580 ± 13	(86.7)
Buffalo milk	80.1 ± 7.3	–	73.9 ± 3.6	–	86.3 ± 4.0	–
[Cow milk equiv (CME)]	[105 ± 10]	–	[97.1 ± 4.7]	–	[113 ± 5.2]	–
Total CME	655 ± 43	(101.1)	617 ± 20	(98.4)	693 ± 18	(103.6)
Hen eggs	57.8 ± 3.8	(8.9 kg ≡118.9 eggs)	54.5 ± 1.5	(8.7 kg ≡115.9 eggs)	61.2 ± 20	(9.1 kg ≡122 eggs)
Meat						
Cattle	59.7 ± 2.5	(9.2)	57.6 ± 1.5	(9.2)	61.9 ± 0.7	(9.3)
Chicken	72.4 ± 8.0	(11.2)	65.5 ± 3.3	(10.4)	79.3 ± 4.7	(11.9)
Pig	99.9 ± 5.3	(15.4)	95.7 ± 3.1	(15.3)	104.1 ± 4.7	(15.6)
Sheep (mutton)	8.2 ± 0.3	(1.27)	7.9 ± 0.1	(1.26)	8.6 ± 0.1	(1.29)
Total meat (composite)	240 ± 16	(37)	227 ± 8	(36.2)	254 ± 8	(38)
Mutton Equivalent	162 ± 10	(25)	153 ± 5	(24.4)	170 ± 4	(25.4)
Chicken Equivalent	309 ± 19	(47.7)	292 ± 10	(46.6)	325 ± 8	(48.6)

Table 12.

Comparative agricultural production scenario (valuewise) of India, China and USA vis-à-vis World production during the first decade of the 21st century (2001-2010) (Production in million US $)

Parameters	India	USA	China	World
Land area (total)- '000 sq km	2973.2	9161.9	9327.5	129611.3
Agricultural land area (million ha)	175.74	395.82	352.14	4011.6
Average population (million ± SD over the decade)	1113.9(±63.9)	295.8(±9.0)	1295.8(±30.3)	6479.9(±240)
Agric. output as % of world output	10.80%	13.60%	22.91%	100
Total agric. output (million $)	144,339±14,517	181,198±10,444	306,258±28,617	1,336,680±95,072
Output/capita ($)	129.6±13.0	612.6±35.3	235.6±17.1	206.3±14.7
Output/ha ($)	821.3±83	457.8±26.4	869.7±81.3	333.2±23.7
Relative share of crop and livestock sectors				
Crop sector (CS) share(%)	69.6±1.5	44.6±1.8	55.4±1.0	48.8±0.6
Livestock sector share (LS) (%)	30.4±1.5	55.4±1.8	44.6±1.0	51.2±0.6
CS output as % of World output	15.40%	12.40%	26.00%	100
Crop sector output total (million $)	100,460±10104	80,814±4658	169,667±15,854	652,300±46,395
Crop sector output/capita ($)	90.2±9.1	273.2±15.7	130.9±12.2	100.7±7.2
Crop sector output/ha($)	571.6±57.5	204.2±11.8	481.8±44.9	162.6±11.6
Crop sector income total (million $)	673,08±6770	311,34±1910	101,800±9512	365,288±25,983
Crop sector income/capita ($)	60.4±61	112.0±6.4	78.6±7.3	56.4±4.0
Crop sector income/ha ($)	383.0±38.5	83.7±4.8	289.1±27.0	91.1±6.5
LS output as % of World output	6.40%	14.70%	20.00%	100
Livestock sector output ($)	43,877±4413	100384±5786	13,659±12,763	684,380±48,617
Livestock sector output/capita($)	39.4±4.0	339.4±19.6	105.4±9.8	105.6±7.5
Livestock sector output/ha ($)	249.7±25.1	253.6±14.6	387.9±38.8	170.6±1.2
Livestock sector income total (million $)	29,399±2957	41,157±2372	81,955±7658	38,3253±27,259
Livestock sector income/capita ($)	26.4±2.7	139.1±8.0	63.2±5.8	59.1±4.2
Livestock sector income/ha ($)	167.3 ± 16.8	104.0±6.0	232.7±21.7	95.5±6.8
Total (CS + LS) income (million $)	96,707±9726	74.291±4282	183,755±17,170	748,541±53,235
Total (CS + LS) income/capita ($)	86.8±8.7	251.2±14.5	141.8±13.2	115.5±7.5
Total (CS+ LS) income/ha ($)	550.3±55.3	187.7±10.8	521.8±48.6	186.6±18.8

There has been a steady increase in production of crop and livestock products and except in case of potatoes low to moderate increase in per capita availability per year could be recorded; only a marginal decrease in potato availability was noted. Among the grains, maize and soybean production and availability were much better than wheat or rice. While vegetable production showed a small increase from the first half-decade to the second half-decade, there has been no increase in per capita availability. Among fruits the availability of grapes and to some extent apples tends to be plateauing but bananas are better off in terms of production and availability. Cotton lint production and availability have been plateaued with 3.5 kg per capita per year over the decade.

Both production and per capita availability of livestock products have shown modest increases from first half to second half of the decade; total cow milk equivalent values increased from 617 mmt/year in the first half to an average 693 mmt/year in the second half with reasonable increase in per capita availability. The same is true for production and per capita availability of eggs.

Although production of cattle meat, chicken meat and pig meat increased modestly, in terms of per capita availability, except for chicken meat a plateau has been reached but despite that average of production of 325 mmt chicken equivalent with per capita availability of 49 kg chicken equivalent meat (or 25 kg mutton equivalent) in the second half of the decade is much higher than that in the average developing countries; obviously such values are attributable to very high availability in high income industrialized countries.

Comparative agricultural scenario (valuewise production) of India, USA, China, and World in the first decade of the 21st century

A comparison of the top three large agricultural economies, China, USA and India, keeping the world (global) agriculture as a reference has been attempted in Table 12 to highlight the major aspects of their current production scenario. We have arranged the economics in an ascending order in terms of the size of the economy with a focus on India at the first place in the table. It is necessary to point out at the very beginning that the production figures (in millions of US dollars) would be different from earlier estimates given for the year 2010 or data for first half-decade (2001-2005) or second half-decade (2006-2010), and are averages covering the full decade(2001-2010). If world production figure is taken as 100, that of India is 10.8%, USA 13.6% and China is 22.9% (nearly the sum of India and USA). The average annual output per capita is highest in the USA ($613), China ($236) and India ($130), the world per capita output is $206. Output per ha in China is $870, followed by India at $821; it is $458 for USA, the same for the world is $333.

The relative share of crop and livestock sectors in overall production are different in the three countries and are as follows: India 70% crop and 30% livestock; USA 45% crop and 55% livestock; China 55% crop and 45% livestock (the world figure is 49% crop and 51% livestock). Compared to the world (taken as 100%) India's total crop output stands at 15.4% (second position), China with 26% is at the top, while USA with a total output of 80,814 million $is at the third position (12.4%). On the other hand, livestock sector output has been 20% of the global output for China, 14.7% of the USA and only 6.4% for India.

Total crop and livestock income per ha has been $550/ha for India, $188/ha for USA and $522/ha for China with the world figure at $187/ha; however, despite lower overall output per ha in the USA, the per capita output is much higher in USA ($613) compared to China ($236) and India ($130) and although input cost in China and India are lower than in the USA income per capita (from crop and livestock sector) is $251 in USA which is nearly three times that of India ($87/capita) and 1.77 times that China ($142/capita). Density of population in the respective countries makes a big impact as is actually shown in Table 4 with Australia with a very low output per ha ($47) has a very high per capita income ($989) although it is a rather special case of a continent sized country with a population that is about equal in number to what India adds each year.

Grain production (in mmt) in the 33 selected countries and conversion of different grains to wheat and rice equivalent values

Total grain production (composite, consisting of different grains) in 2010 (Table 6, 29) has been highest in China (490 mmt), followed very closely by USA (478 mmt). It needs to be pointed out that the total (composite) amounts do not include other grains such as barley, rye, oat etc. if any (as included in the Table 5), as such total grain figure in this table may for several countries be somewhat lower because rice, wheat, maize and soybean only have been considered here and data expressed as rice equivalent or wheat equivalent mmt (million metric tonnes) based on factors derived from their respective price per metric ton. Producer's price in 2010 per metric ton of the four grain has been estimated at rice $260, wheat $125, maize $65 and soybean $248 (Table 20); as such, the relative weights are as follows: rice 1.0, wheat 0.481, maize 0.250 and soybean 0.954; once rice equivalence is calculated the same can be converted to wheat equivalence (wheat 1.0, rice 2.08, maize 0.52, soybean 1.98) and so on using the required factors. Comparison of the grain producing capacity of a country should be based on any scale of equivalence rather than on total (composite) grain production. Rice valuewise is 4 times more than maize, as such 4 times more maize will be required to equalize rice. China and USA are so close in composite grain production but the difference becomes magnified as China is rich in rice production, USA in maize production. India produces maize and soybean but that has not been sufficient enough to be included in FAO data for 2010, even then it occupies the third place in grain production because of rice and wheat production amounting to 201 mmt (composite) (Table 29) with rice and wheat equivalents of 159 mmt and 331 mmt, respectively. Brazil with very little rice but good amount of soybean (second to USA) and maize is the fourth largest grain producer with rice and wheat equivalents of 94 mmt and 195 mmt, respectively.

Global Climate Change

Some important observations from the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) on greenhouse gas emissions (IPCC, 2007) are worth recapitulation here:

1) Global anthropogenic GHG emission showed an increase of 70 percent between 1970 and 2004.

   Over the 10-year-period of 1995-2004, the rate of GHG emission has been 0.92 gt/yr during the period 1970-1994.

2) The share of different GHGs in total emissions in terms of CO_2 equivalent values in 2004 has been as follows (total emission taken as 100) : (i) CO_2 total (from all sources)= 76.7% (fuel use 56.6%, decay of biomass and deforestation 17.3%, others 2.8%), (ii) methane (CH_4) from agriculture and other sources= 14.3%, (iii) nitrous oxide (N_2O from agriculture and other sources = 7.9% and (iv) F-gases (fluorinated gases, HFCs, PFCs and SF_6) = 1.1%.

3) The share of different sectors in total anthropogenic GHG emissions in terms of CO_2 equivalent values in 2004 were as follows (total emission = 100) : (i) energy supply 25.9%, (ii) industry 19.4% (iii) forestry (including deforestation) 17.4% (iv) agriculture (all sectors) 13.5% [agriculture, deforestation, land use changes 30.9%], (v) transport 13.1%, (vi) residential and commercial buildings7.9%, (vii) waste and waste water 2.8%.

Agriculture, changed land use and deforestation all of which are closely integrated would collectively account for the maximum GHG emission (nearly 31%) and consequently with the biggest global warming potential (IAASTD, 2008).

Also relevant in this connection are the conclusions of the IPCC in the form of a few general statements, such as : (i) warming of the climate system is unequivocal and most of the observed increase of the globally averaged temperature since the mid-twentieth century is very likely due to an observed increase in greenhouse gas concentrations, (ii) temperature changes between 1951-80 average and 2000-2008 average were greatest in the polar regions and higher latitudes (more than 2°Celsius), (iii) impact of agriculture will be greater in countries in the low latitudes because of already prevailing high temperatures.

A doubling of the atmospheric CO_2 concentration above pre industrial levels (280 ppm prior to the industrial revolution around 1750) with eventual global warming is called "benchmark 2 x CO_2 warming"; globally the warming at 560 ppm atmospheric CO_2 concentration is expected to be around 3°C (with the possibility of large deviations due to various factors) in the late 2080s.

Greenhouse gas emission in selected 33 countries

With the aforesaid background let us examine the GHG emissions in the 33 selected countries of the world (vide Table 13). The highest emission of CO_2 (year 2006) was in the USA (5788 mmt, per capita emission (PCE) 19.3 ton), followed by China (6099 mmt, PCE 4.7 ton), Russian Fed. (1564 mmt, PCE 11 ton), India (1509 mmt, PCE 1.4 ton), Japan (1293 mmt, PCE 10.1 ton), Germany (805 mmt, PCE 9.8 ton), UK (568 mmt, PCE 9.4 ton), Canada (554 mmt, PCE 16.7 ton. Though total emission in Australia is not much (372 mmt), per capita emission (PCE) in the country is next to USA (18.0 ton). Countries like Zambia (3 mmt), Madagascar (3 mmt), Cambodia (4 mmt), Cameroon (4 mmt), Sri Lanka (12 mmt), Kenya (12 mmt) etc. are low emitters of CO_2. Methane emission (expressed in CO_2 equivalent) is highest in China (1288 mmt) accounting for 18% of global methane emission, it is distantly followed by USA (611 mmt), India (590 mmt), Russian Fed. (557 mmt) and Brazil (483 mmt). Agriculture is a big source of emission (31- 78% depending on the country). Among the countries nitrous oxide emission is highest in China (415 mmt CO_2 eq.) followed by USA (257 mmt), Brazil (256 mmt), India (196 mmt), Indonesia (165 mmt), Russian Fed. (69 mmt), Myanmar (64 mmt) and Australia (58 mmt). The emission of fluorinated gases (F-gases) with very high global warming potential (GWP) is highest in the USA (239 mmt CO_2 equivalent, accounting for one third of the global emission),followed by China (139 mmt), Russian Fed.(59 mmt), Japan (53 mmt), Canada (22 mmt), France (16 mmt), Italy (14 mmt), Brazil (12 mmt), UK (10 mmt).It is worthwhile to note that China is the second highest emitter of F-gases and has been responsible for 1075% change (increase) in F-gas emission during the period 1990-2000 while for the highest emitter USA, the changes in the aforesaid period has been 159% (increase); as such it is high time both the countries should review their stand specially from the standpoint of stratospheric ozone destruction.

A very pertinent issue in GHG emission is the fact that the big emitters are fully aware that the gases have no regard for the national boundaries and would readily pass into the atmosphere with adverse consequence on the countries that are low and even zero emitters. A global consensus is essential is also well known but the same is cunningly avoided by the principal perpetuators of the crisis.

Climate Models: General Circulation Models (GCM) of Climate Systems

General circulation models of earth's climate systems are generated through extensive and very complex computations involving a wide range of interacting factors and requiring the use of supercomputers by highly trained subject matter specialists. The main factor is to simulate the diverse physical forces involving the atmosphere and oceans that conjointly develop and regulate the earth's dynamic climate systems and specifically the sensitivity of climate to different concentrations of greenhouse gases (GHGs). The GHGs have varying capacities to trap outbound long-wave length radiations and cause warming up of the atmosphere. The temperature change if sufficiently large would have a profound effect on physical processes such as evaporation, air circulation, extent and pattern of precipitation and related events.

There are quite a few important GCMs that would project future temperature rise attributable to GHGs along with other changes (precipitation, air circulation etc). It, however, needs to be emphasized that despite their basic commonality on a broad scale, there are significant quantitative differences and disagreements among these computer generated estimates of different GCMs especially at country and regional levels rather than at the global level.

GCMs developed by different modelling centres use different grid resolutions and temperature sensitivity (see Table 15). Geographic grids represents a system of numbered squarish or rectangular areas (cells of a network, called grid cells) that are printed on a map forming the basis of map references) in terms of latitudes and longitudes; with individual grid cells in a map usually covering an area of 1^{o} latitude x 1^{o} longitude, or otherwise depending on the particular climate model in case of GCMs. However, for the sake of comparison, the observed and model output data ought to be scaled to a standard grid (G). G is defined to have 90 latitudes and 120 longitudes and would comprise 10800 cells each with a dimension of 2^{o} x 3^{o} spanning 180^{o} x 360^{o} of the globe.

Application of Agricultural Impact Models

The application of climate models by Cline (2007), taking the average across 6 GCMs (for a consensus approach) vis-a-vis two major agricultural impact models (Ricardian model and Crop model) was undertaken to estimate the corresponding prospective effects for agricultural capacity countrywise or regional groupings of smaller countries. The Ricardian models, so named after the classical economist David Ricardo would relate agricultural capacity to temperature and precipitation in a nonlinear fashion.

The crop models also known as agronomic models, take into consideration the agronomic performance of crops (grains, oilseeds etc as studied by scientists from 18 countries) as affected by climate change (there are also other models such as models based on land zone studies premised on the shift of geographical areas from one agronomic class to another because of climate change). The agricultural impact models are expected to be closely related to the GCMs that project future temperature changes attributable to GHGs and altered precipitation regimes. The Ricardian agricultural impact models (also known as Cross Section, CS models) have been developed by Mendelsohn and co-workers (Mendelsohn and Schlesinger,1991; Mendelsohn *et al.,* 1991, 2001, 2006) taking consideration of the change in land rental value due to climate change and working out regressions across climate zones.

The crop models are based on region specific calculations synthesized from estimates by agricultural scientists as applied to alternative GCM projections of climate scenarios (Rosenzweig *et al.,* 1993; Rosenzweig and Iglesias, 2006). As stated earlier, compared to the Ricardian approach of indirect inference of climatic effects, the input-output oriented process calculation would be a more direct approach. As such, depending on the nature of data from different countries Cline (2007) has developed the "preferred estimates" that are either average of Ricardian and Crop models (equal weight to both) or greater weightage (two-third weightage) given to Crop model than the Ricardian model (one third weightage). According to Cline (2007), the preferred synthesis approach would permit more balanced set of estimates than applying models from one family to the exclusion of the other.

Climate Change: Changes in average temperature and precipitation during 1961-90 and 2070-99

Temperature: Of the 33 countries listed in Table 14, 20 countries have average temperature at or above 20^0 C, 13 countries are below 20^0 C temperatures (Pakistan with 19.91 C is in the border line, Table 14). In the late 2080s countries are projected to have a temperature rise ranging from 2.73^0 – 2.20^0 (Russian Fed. In which the average temperature during 1961-90 was – 3.93^0 C, slightly higher than Canada, its close latitudinal partner with – 4.92^0 C). Broadly, the increase is around 3^0 to 4^0 C. So far as temperate countries are concerned, those with average temperature around 10^0 C will certainly benefit with such temperature rise but there is strong likelihood for adverse agricultural impacts on countries with average temperatures above 20^0 C. Cline (2007) has rightly pointed out that in majority of the developing countries the existing temperatures are above the optimum levels, therefore further global warming would reduce agricultural production capacity.

Precipitation: Precipitation determines the key issue of the availability of water; unlike temperatures which in all countries would show significant increases, rainfall or snowfall would be characterized by ups and downs. In fact the IPCC (2001) stated that tropical areas would have increased mean precipitation, most of the subtropical areas would show decreased mean precipitation while in the high latitudes the mean precipitation would increase.

Regarding the projected changes in precipitation in selected countries (Table 14), the increase in Bangladesh from the base average of 6.42 mm /day during 1961 – 1990 to 7.0 mm/day in 2070 -2099 (an increase of 0.62 mm) is the highest, followed by + 0.55 mm/day in Canada (but from a much lower base value of 1.15 mm /day) and India (+ 0.47 mm from a base value of 2.8 mm/day), Myanmar (+ 0.44 mm from a base value of 5.47 mm/day), Russian Fed. (+ 0.32 mm from a base value of 1.25 mm/ day), China (+ 0.31 mm from a base value of 2.24 mm/day), Thailand (+ 0.31 mm from a base value of 4.38 mm/day), Sri Lanka (+ 0.29 mm from a base value of 4.67 mm/day), Indonesia (+ 0.28 mm from a base value of 7.74 mm/day), and UK (+ 0.24 mm from a base value of 3.13 mm/day). The decrease in precipitation is highest in Spain(-0.33 mm from a base vale of 1.76 mm/day) followed by Mexico (- 0.25 mm from a base value of 2.09 mm/day) , Madagascar (-0.21 from a base value of 4.12 mm/day), France (-0.20 mm from a base value of 2.33 mm/

Table 13.

Greenhouse gas (GHG) emission in selected 33 countries Countrywise emission in million metric tonnes (mmt) of carbon dioxide (for 2006) or as Co_2 equivalent values in mmt for methane and nitrous oxide (for 2005) and other green house gases (F- gases for 2000). See text for further details.

Sl. No	Countries	Carbon dioxide		Methane		Nitrous oxide		F-Gases	
		mmt	per capita (mt)	mmt	% agriculture emission	mmt	% agriculture emission	mmt	% change (1990-2000)
1	**Argentina**	173	4.4	101	71	36	90	0.79	-66
2	**Australia**	372	18. 0	120	58	58	85	6.51	33
3	**Bangladesh**	42	0.3	93	70	21	83	0	0
4	**Brazil**	352	1.9	483	62	256	55	11.81	40
5	**Cambodia**	4	0.3	-	-	-	-	0	0
6	**Camaroon**	4	0.2	20	76	6	60	0	0
7	**Canada**	554	16.7	73	36	33	64	21.9	70
8	**China**	6,099	4.7	1,288	40	415	82	137.1	1085
9	**Colombia**	63	1.5	58	69	23	80	0.08	100
10	**Cuba**	30	2.6	9	62	6	83	0.13	0
11	**Egypt**	167	2.1	46	32	18	85	3.18	54
12	**France**	383	6.2	80	46	46	71	15.54	57
13	**Germany**	805	9.8	57	52	53	68	0.2	-97
14	**India**	1,509	1.4	590	64	196	77	8.43	-12
15	**Indonesia**	333	1.5	209	46	165	53	1.03	-41
16	**Italy**	474	8	40	40	26	48	13.58	214
17	**Japan**	1,293	10.1	39	78	23	36	52.74	106
18	**Kenya**	12	0.3	20	72	10	90	0	0
19	**Madagascar**	3	0.2	-	-	-	-	0	0
20	**Mexico**	436	4.2	127	43	41	77	4.56	53
21	**Myanmar**	10	0.2	77	69	64	20	0	0
22	**Netherlands**	168	10.3	21	44	14	42	3.74	-41
23	**Pakistan**	143	0.9	138	63	26	77	0.82	-19
24	**Philippines**	68	0.8	51	64	12	81	0.37	131
25	**Russian Fed.**	1,564	11	557	9	69	48	58.6	130
26	**South Africa**	414	8.7	62	33	21	70	2.17	46
27	**Spain**	352	8	38	55	23	71	9.08	49
28	**Sri Lanka**	12	0.6	10	65	2	73	0	0
29	**Thailand**	272	4.1	81	68	20	71	1.1	-23
30	**United Kingdom**	568	9.4	42	59	28	65	10.4	97
31	**United States**	5,748	19.3	611	31	257	59	238.51	159
32	**Vietnam**	106	1.3	84	63	22	87	0	0
33	**Zambia**	3	0.2	19	62	31	59	0	0
	WORLD	**30,155**	**4.4**	**7,138**	**43**	**2,828**	**64**	**715.4**	124

Total GHGs (mmt) = 40,836.4 (World total CO_2 - equiv value in mmt)
Relative share of GHGs CO_2 = 73.8% , CH4 =17.5% , N_2O = 6.9%, F-gases = 1.8%
Source : 2010 World Development Indicators (World Bank)

Table 14.

Changes in climate in the late twenty first century : Average temperature and precipitation [annual averages of temperature (°C)and precipitation, (mm /day) during 1961 -90 and 2070-99]

Sl. No	Countries	Temperature °C			Precipitation, mm/day		
		1961-90	2070-99	Temp rise(°C)	1961-1990	2070-99	Change (+/-)
1	**Argentina**	14.65	17.89	3.24	1.63	1.66	0.03
2	**Australia**	21.38	25.16	3.76	1.48	1.43	-0.05
3	**Bangladesh**	24.46	28.13	3.67	6.42	7.04	0.62
4	**Brazil**	24.55	28.58	4.03	4.51	4.5	-0.01
5	**Cambodia**	26.64	29.99	3.35	5.31	5.21	-0.1
6	**Cameroon**	24.6	28.16	3.56	4.36	4.5	0.14
7	**Canada**	-4.92	-1.31	3.61	1.15	1.7	0.55
8	**China**	9.63	14.68	5.05	2.24	2.55	0.31
9	**Colombia**	24.31	27.81	3.5	7.25	7.44	0.19
10	**Cuba**	25.25	28.19	2.94	3.57	3.5	-0.07
11	**Egypt**	22.16	26.79	4.63	0.12	0.12	0
12	**France**	10.56	14.95	4.39	2.33	2.13	-0.2
13	**Germany**	8.26	12.7	4.44	2	2.09	0.09
14	**India**	24.27	27.86	3.59	2.8	3.27	0.47
15	**Indonesia**	25.76	28.58	2.82	7.74	8.02	0.28
16	**Italy**	12.3	16.52	4.32	2.48	2.23	-0.15
17	**Japan**	10.73	14.87	4.14	4.4	4.46	0.06
18	**Kenya**	24.33	27.83	3.5	4.02	4.19	0.17
19	**Madagascar**	22.28	25.53	3.25	4.12	3.91	-0.21
20	**Mexico**	20.66	24.71	4.05	2.09	1.84	-0.25
21	**Myanmar**	22.67	26.08	3.41	5.47	5.91	0.44
22	**Netherlands**	9.26	13.21	3.95	2.16	2.31	0.15
23	**Pakistan**	19.91	24.76	4.85	0.83	0.96	0.13
24	**Philippines**	25.51	28.24	2.73	6.52	6.68	0.16
25	**Russian Fed.**	-3.93	3.27	7.2	1.25	1.57	0.32
26	**South Africa**	17.72	21.89	4.17	1.31	1.2	-0.11
27	**Spain**	13.24	17.9	4.66	1.76	1.43	-0.33
28	**Sri Lanka**	26.8	29.64	2.84	4.67	4.96	0.29
29	**Thailand**	26.2	29.39	3.19	4.38	4.69	0.31
30	**United Kingdom**	8.51	11.76	3.25	3.13	3.37	0.24
31	**United States**	9.47	13.99	4.52	1.85	1.95	0.1
32	**Vietnam**	24.09	27.44	3.35	4.87	4.94	0.07
33	**Zambia**	21.57	25.86	4.29	2.75	2.61	-0.14
	WORLD						
	Land area weighting	13.15		4.95	2.2		0.129 (5.9%)
	Form area weighting	16.2		4.43	2.44		0.072 (2.9%)

Table 15.

Dispersion of Mendelsohn - Schlesinger Ricardian model estimates across Percent change in land rental equivalent climate models (without carbon fertilization)

Country	Climate Models							
	CCSR	HadCM	GFDL	EC HAM	CSIRO	CgCM	Consensus Estimate	CV
Argentina	-20.5	-17	-9.8	-11.6	-15.1	-15.7	-14.8	0.57
Brazil,Southern	-100	-100	-67.1	-100	-86.8	-89.7	-99.2	0.32
Chile	18.7	16.8	18.2	16.8	18.2	19.7	18.2	0.14
China.Central	26.4	23.5	23.5	28.9	29.2	23.5	27.1	0.24
China, South Central	-47.3	-34.8	-22.2	-29.3	-26.2	-32.5	-31.4	0.61
Colombia	-100	-100	-100	-100	-100	-100	-100	0
Germany	31.2	28.8	28.3	32.2	26.6	24.7	30.6	0.22
Madagascar	-95.9	-77.8	-74.1	-97	-70.8	-80.6	-81.6	0.3
Mexico	-100	-80.8	-60.3	-68.9	-53.8	-52.8	-71.8	0.59
New Zealand	6	10.5	11.7	11.9	10.3	11.3	10	0.48
Russia,Caspian Black sea	33.8	41	33.9	41.9	40.1	40	41.1	0.21
South Africa	-42.4	-39.5	-32.3	-43.5	-30.5	-39.6	-37.7	0.32
Turkey	-7.7	2.8	5.8	4.1	3.4	5.3	3.5	4.89
United Kingdom	26.9	18.4	22.8	25.4	21.1	18.5	23.4	0.35
US Lakes and Northeast	25.9	32.9	32.8	36.9	36.1	33.3	35.4	0.26
US South East	-64.6	-34.8	-23.9	-22.6	-31.2	-31	-33.3	0.99
Venejuela	-100	-100	-100	-100	-100	-100	-100	0
Zambia	-100	-99.9	-69.1	-100	-67.8	-90.5	-91.3	0.39

Full names of models along with their grid resolutions and climate sensitivity in °C in parenthesis :
CCSR/NIES : Japanese Centre for Climate System Research (grid 5.6° x 5.6°; sensitivity 3.5°C)
HadCM3: UK Hadley Centre for Climate Prediction,Model3(grid 2.5°x 3.75°;3.0°C)
GEDL: US Geophysical Flms Dynamics Laboratory (2.25° x 3.75°; 3.4 °C)
EC HAM4/ OPYC 3: German Climate Research Centre/ Hamburg Model 4 (2.8° x 2.8° ; 2.6°C)
CSIRO- MK 2 : Australian Commonwealth Scientific and Industrial Research Organization; Model 2b (3.2° x 5.6°; 3.7°C)
CgCM 2: Canadian Centre for Climate Modelling and Analysis GCM2(3.7° X 3.7°; 3.6°C)
Source : Cline (2007) only data of selected countries considered here

day), Italy (-0.15 mm from the base value of 2.48 mm/day), and Zambia (- 0.14 mm from a base value of 2.7 mm /day). Egypt would not show any change from its low base value of 0.12 mm/day.

The IPCC (2001) in its colour graphic presentation of precipitation change by 2070-2099 has predicted increased precipitation to the tune of 20% at latitudes higher than 60^0 and patch of 20% or more increase across the Sahara deserts and into the Arabian peninsula (of course from a minimal base precipitation). Precipitation is projected to decline by 5-10% for Mexico, southern United States, the eastern half of Brazil and western half of Argentina, most of Australia and the Mediterranean region. An increase of

0-5% for much of the sub-Saharan Africa, China and Russia, northern USA and Canada is also predicted.

Dispersion of Mendelsohn-Schlesinger Ricardian Model estimates across climate models

Percentage change in land rental equivalent: The dispersion of Ricardian Agricultural Impact model across the six climate models shows countrywise impact estimates (including regions within big countries) and respective averages (consensus estimate) along with coefficient of variation (CV, ratio of standard deviation and mean). Cline (2007) has reported the results of 30 major countries or regions and we have selected 18 out of them specially those enlisted in our 33 selected countries besides few others in Table 15. The estimates clearly show that all the six models broadly agree on whether the agricultural impact would be positive or negative and how much is the quantitative difference between the models for a particular country or region. For most of the countries such information could be fairly adjudicated from standard deviation values or coefficient of variation (expressed as a ratio or percentage). For most countries they are within acceptable limits; as such, Cline's observations support the use of consensus climate model approach and indicate that in estimating country specific impacts, variability across the agricultural-economic models is more important than variability across the climate models.

Nevertheless, the large declines in land rental equivalence for many of the countries (Colombia 100%,Venezuela 100%,Southern Brazil 99.2%, Zambia 91.3%, Madagascar 81.6%, Mexico 71.8%) are really dire predictions. Russia's Caspian Black Sea region (+ 41.1%), US Lakes and North-east (+ 35.4%), Germany (+ 30.6%), Central China (+ 27.1%), UK (+ 23.4%) are projected to gain (may be for a century) from global warming.

Rosenzweig-Iglesias impact estimates for the 2080s using the crop agronomic model (percent change in yield)

Data presented in Table16 show the dispersion of the crop (agronomic) model of Rosenzweig-Iglesias across four climate models for assessment of impacts on agriculture of 18 countries (originally 32 countries and regional groups enlisted by Cline (2007) out of which 18 countries have been chosen by the present authors). For USA, the reduced form crop model function by Mendelsohn and Schlesinger(1999) has been adopted as an alternative model and have been given equal weight with Rosenzweig-Iglesias estimates for the USA (Cline 2007). Otherwise the estimates come from a different conceptual approach as crop or agronomic models developed on the basis of agronomic studies rather than through regression analyses.

In any case, the decline in yield (as averaged over the four climate models) would be very high in Pakistan (- 25.5%) followed by Mexico (- 23.8%), Egypt (- 18.8%), Brazil (- 16.3%), India (- 14.3%) etc. Among the 18 countries listed in the table, New Zealand is projected to show an increase in yield to the tune of 18.8%.

As has been recorded earlier in case of Ricardian models, here also variation across agricultural- economic models is more important than variability across the climate models. However, variability within the rows (climate models) is quite appreciable indicating larger coefficients of variation for many of the countries. The issue needs careful consideration and as would be seen in the next table (Table 17), the same has been effectively tackled by Cline (2007) through development of "preferred estimates"; mathematically averaging of data with high variability would also reduce standard deviation and CV (standard deviation expressed as percentage of mean or taking the ratio of SD and mean).

"Preferred estimates" of climate change impacts without or with carbon fertilization (values stand for percent change in 2080s)

Data presented in Table 17 taken from Cline (2007) wherein preferred estimates for climate change have been derived from Ricardian and Crop models for 18 countries along with data for world, as well as developing and industrial countries.

As regards global level impacts, there appears to be more severe (total) effects in the crop model estimates than in the Ricardian estimates either without or with carbon fertilization. Without CF, the values are -19% and -10% for crop model and -22.5% in the Ricardian and for industrial countries it is +1.9 in the Ricardian and -11.5 in the crop model, without CF. Similar trend is recorded with CF as well, despite the overall beneficial effects of CF.

Table 16.

Rosenzweig- Iglesias agricultural impact estimates for the 2080s using the crop model: percent change in yield of four major grains and oil seeds

Sl. No	Countries	Climate Models				Average
		Had CM3	GISS	GFDL	UKMO	
1	**Argentina**	5	-3	-7	-10	-3.8
2	**Australia**	-7	6	6	6	2.8
3	**Brazil**	-25	-12	-7	-21	-16.3
4	**Canada**	-1	24	25	2	12.5
5	**China**	-2	8	2	3	2.8
6	**Egypt**	-13	-17	-13	-32	-18.8
7	**India**	-13	-4	-13	-27	-14.3
8	**Indonesia**	-1	-14	-6	1	-5
9	**Japan**	-2	14	10	7	7.3
10	**Kenya**	-9	-14	-14	-14	-12.8
11	**Mexico**	-17	-27	-20	-31	-23.8
12	**New Zealand**	8	29	24	14	18.8
13	**Nigeria**	-19	-6	-16	-6	-11.8
14	**Pakistan**	-18	-29	-5	-50	-25.5
15	**Soviet Union (Former), E. Europe**	-16	16	5	-7	-0.5
16	**Thailand**	-4	-19	-8	-24	-13.8
17	**Turkey**	-12	-5	-15	-15	-11.8
18	**United States**	-5	5	-2	-13	-3.8

Note : (1) Estimates include full carbon fertilization effect and "level 1" adaptation. The four grains are wheat, rice, maize and soybean. (2) The climate models are UK Hadley Centre for Climate Prediction and Research Coupled Model 3 (Had CM3), Goddard Institute for Space Studies, USA (GISS), USA Geophysical Fluid Dynamics Laboratory (GFDL) and UK Meteorological Office (UKMO).

Original source : Rosenzweig and Iglesias(2006) as calculated by Cline (2007)

Table 17.

Climate change impacts on agriculture (selected countrywise impacts; and overall impacts on the World's developed and developing countries in terms of median of regions and totality) Ricardian and Crop models and Cline's "Preferred estimates" derived from ,Cline (2007); impacts without and with carbon fertilization

Sl. No	Countries	Without carbon fertilization			Mode of Preferential approach (a1/a2)	With carbon fertilization		
		Ricardian Model	Crop Model	Preferred estimates		Ricardian Model	Crop Model	Preferred estimates
1	**Argentina**	-4.1	-18.1	-11.1	a1	10.3	-5.8	2.2
2	**Australia**	-55.1	-12.6	-26.6	a2	-48.3	0.6	-15.6
3	**Brazil**	-5	-28.7	-16.8	a1	9.3	-18	-4.4
4	**Canada**	0	-4.3	-2.1	a1	15	10.1	12.6
5	**China**	3.6	-12.6	-7.2	a2	19.2	0.6	6.7
6	**Egypt**	53.5	-30.9	11.3	a1	76.5	-20.5	28
7	**India**	-49.2	-27	-38.1	a1	-41.6	-16.1	-28.9
8	**Indonesia**	-15.3	-19.1	-17.9	a2	-2.6	-7	-5.6
9	**Japan**	0.4	-8.7	-5.7	a2	15.4	5	8.4
10	**Kenya**	15	-25.7	-5.4	a1	32.3	-14.6	8.8
11	**Mexico**	-35.9	-35.1	-35.4	a2	-26.3	-25.4	-25.7
12	**New Zealand**	4.5	1,1	2.2	a2	20.2	16.2	17.5
13	**Nigeria**	-12.1	-24.9	-18.5	a1	1.1	-13.6	-6.3
14	**Pakistan**	-17.9	-36.6	-30.4	a2	-5.6	-27.1	-20
15	**Soviet Union (Former)**	8.1	-15.3	-6.7	a2	24.3	-2.6	7.3
16	**Thailand**	-25.3	-26.6	-26.2	a2	-14.1	-15.6	-15.1
17	**Turkey**	1.6	-24.9	-16.2	a2	16.8	-13.6	-3.6
18	**United States**	4.7	-16.5	-5.9	a1	20.4	-3.9	8.2
	WORLD							
	Median of regions	-14.5	-25.5	-23.6	a2	-1.7	-14.4	-12.1
	Total	-10	-18.9	-15.9	a2	3.5	-6.8	-3.2
	Developing countries							
	Median of regions	-21.3	-27	-25.8	a2	-9.5	-16.1	-14.7
	Total	-16.9	-22.5	-21	a2	-4.5	-10.8	-9.2
	Industrial countries							
	Median of regions	2.4	-9.9	-5.7	a2	17.8	3.6	8.4
	Total	1.9	-11.9	-6.3	a2	17.2	1.3	7.8

Note : Mode of preferiential approach a1 : average of Ricardian and Crop model in preferred estimate, a2 : Preferred estimate based on 1/3 rd weight Ricardian , 2/3 rd weight of Crop model

The Ricardian estimates, both without CF or with CF are very severe for Australia (-55% without CF and -48% with CF), India (-49% without CF, -42% with CF), Mexico (-36% without CF, -26% with CF, of course crop model would also corroborate that). The corresponding values using the crop models for Australia, are much more sobering (Australia -12.6 without CF, +0.9 with CF); the same is partly true for India (-27% without CF, -16% with CF). Interestingly USA in Ricardian model is +4.7% (without CF) and + 20.4 (with CF) against -16.5% (without CF) and -6.8% (with CF) in the crop model. Thailand shows consistent adverse effects with both the models. The two pragmatic approaches either a1 (average of two models with equal weights) or a2 (two-third crop model plus one third Ricardian) similar proposition would likely be a matter of general agreement among specialists working on climatic change impact models on agriculture.

Table 18 is an extension of "preferred estimates" approach of Cline (2001) depicting regional, country-wise (a selected group of countries) and on global scenario on impact of climate change vis-a-vis population, base output (billion $),output per hectare ($) for countries and change in output potential in terms of percent change as well as in billions of dollars for regions, countries and world without and with carbon fertilization (CF), with all estimations of change based on " Preferred estimates" as discussed in Table 17. It is seen that output weighted agricultural potential with carbon fertilization rises for industrial countries by a preferred estimate of 7.7% which for developing countries (excluding Europe) falls to - 9.1%. Further with the preferred estimate with CF output potential is -16.6% in Africa (excluding North Africa), - 7.2% in Asia, - 9.4% in Middle East and North Africa and -12.9% in Latin America. On the other hand for developing countries it is 7.7% with CF and -19.7% without CF – a probable 12% gain attributable to CF.

The results based on preferred estimates are consistent with IPCC observation in 1996 and give the following projections for the late 21st century.

i) Africa (excluding Egypt and other North Africa) and Latin America are the two developing regions most vulnerable to global warming.

ii) Asia on an average is less vulnerable. But it is primarily due a compensation by China with more favourable output against a quite unfavourable results in agricultural output by India situated in the lower latitudes.

iii) Global agricultural potential (weighting by output) falls by above 16 percent without CF, and by 6 percent with CF. On weighting by population, output potential falls by a weighted average of 18 percent without CF and by about 6% with CF.

In terms of billions of dollars (2003 $ value), the projected loss for developing countries will be $163 billion without CF and $68 billion with CF. The output potential without CF as per preferred estimate would be negative for all regions and countries. It is -10 billion $ for Africa, - 27 billion $for Latin America, - 8.7 billion $ for Europe, - 21 billion $for Industrial countries and globally –187 billion dollars; the corresponding values with CF are respectively - 12 billion $ (Africa), - 36 billion $ (Asia), - 6 billion $ for (E.N. Africa), - 14 billion $ (Latin America), + 3.8 billion $ (Europe), + 26 billion $ (Industrial countries) and - 38 billion $ (World). The losses and gain for countries within the region are shown in the table in percentage and 2003 dollar value (in billions).

Cline's summary table on impact on world agricultural output potential by 2080s very briefly and explicitly brings out the climate change effects on agriculture (Table 19) and categorically brings out the fact that the industrial countries (OECD countries) stands to gain nearly 8% if carbon fertilization due to enhanced level of carbon dioxide in air (a major input for photosynthesis) boosts up carbon assimilation as projected by Ricardian and Crop models otherwise they would also suffer a loss of productivity, albeit to a tolerable level (6.3%, based on preferred estimate of Cline, 2007).

Producer's Price of Agricultural Commodities (World data over 2001-2010 vide FAOSTAT database)

The producers' prices of agricultural commodities under the crop and livestock sectors in the first decade of 21st century as presented in Table 20 have been calculated for each item by dividing total production figures of the world (in billion or million dollars) by respective thousands of metric tonnes of each product giving the price per tonne of the particular commodity. The most interesting (and surprising as well!) finding is the fact that over a period of 10 years there has been little or no change in the price of primary agricultural commodities. The mean value along with standard deviation values indicate that agricultural prices, except a few are more or less stable for both crop and livestock sectors. Only significant increase has been in case of maize which shows 44% rise over the decade (annually around 4.4%). There is absolutely no difference in price between 2010 and 2001 in case of grapes, bananas, sugarcane, and cotton and very small difference in others. Among the livestock products, only milk shows a coefficient of variation (CV, percent) of 0.4; price of all other items remained the same over the 10-year period, a situation that would appear rather unusual.

Primary agricultural commodity prices in the international market: It would be pertinent in this connection to study the primary agricultural commodity prices (including the fertilizer used in farming) and analyze the price structure and relevant issues. Data presented in Table 21 on primary commodity prices in the international market during the 5-year period (2005-2009), show 93-103% price increase between the highest and lowest prices in case of grains that include barley, maize, sorghum and wheat. Its needs to be emphasized that the international price of rice (Thailand) was 260 $/ton in 2005 that went up to 467 $/ton in 2009; producers price of rice was 260 $/ton in both the years (Table 20). The difference was 70% for sugar, 30% and 19% for bananas and oranges respectively but only 5% for beef.

Price of maize in the international market was 90 $/ton in 2005,the same was 51 $/ton as per FAOSTAT producer's price (Table 20) which has gone up to 65$/ton in 2009 against the international market price of 139$/ton (more than double the FAOSTAT price).

Fats and oil that include coconut oil, groundnut oil, palm oil, soybean oil etc. show 74-103% difference between the highest and lowest prises of each commodity over a 5-year period. As regards the prices of beverages and agricultural raw materials like rubber, tobacco etc. we could not consider and compare their prices as they could not be accommodated in the FAOSTAT world data sheet that would not go beyond 20 commodities, nevertheless in the international market cotton, rubber and tobacco prices show differences between highest and lowest prices to the tune of 15, 53 and 38% respectively. Incidentally, the cotton lint price as calculated from FAOSTAT data remained unchanged at $1429 per ton throughout the period 2001-2010 (Table 20).

It is true that a major share of the large CV (coefficient of variation, values expressed in percent) values would be attributable to 2008, the year of global financial crisis whereby prices

Table 18.

Impact of climate change on agriculture, with or without carbon fertilization (CF), in Developing and Industrial countries using preferred estimates of Cline (2007)

Region/ Countries	Population 2003 (million)	Base output 2003 billion US $	Output/ha	Change in output potential			
				Without CF(%)	billion $	With CF	billion $
Developing countries	5202	838		-19.5	-163	-7.7	-65
Excluding Europe	4807	745		-21	-156	-9.1	-68
Africa	660	73		-27.5	-20	-16.6	-12
Nigeria	136	15	460	-18.5	-2.8	-6.3	-0.9
South Africa	46	6	407	-33.4	-2	-23.4	-1.4
Asia	3362	500		-19.3	-97	-7.2	-36
China	1288	213	1381	-7.2	-15	6.9	14.7
India	1064	132	777	-38.1	-50	-28.8	-38
Indonesia	215	35	1051	-17.9	-6.3	-5.6	-2
East North Africa	280	61		-21.2	-12.9	-9.4	-5.7
Algeria	32	7	787	-36	-2.5	-26.4	-1.8
Egypt	68	13	3516	11.3	1.5	28	3.6
Iran	66	15	883	-28.9	-4.3	-18.2	-2.7
Latin America	506	111		-24.3	-27	-12.9	-14.3
Argentina	37	14	83	-11.1	-1.6	2.2	3.1
Brazil	177	30	84	-16.9	-5.1	-4.4	-1.32
Mexica	102	25	136	-35.4	-8.9	-25.7	-6.4
Europe	395	93		-9.4	-8.7	4.1	3.8
Poland	38	5	239	-4.7	-0.2	9.5	0.5
Russia	143	22	87	-7.7	-1.7	6.2	1.4
Turkey	71	27	935	-16.2	-4.4	-3.6	-1
Industrial Countries	840	338		-6.3	-21	7.7	26
Australia	20	13	29	-26.6	-3.5	-15.6	-2
Canada	32	17	254	-2.2	-4.04	12.5	2.1
Germany	83	17	881	-2.9	-0.5	11.7	2
United Kingdom	50	13	760	-3.9	-0.5	10.5	1.4
United States	291	99	260	-5.9	-5.8	8.2	8.1
WORLD	6049	1176		-15.9	-187	-3.2	-37.6
Population weighted				-18.2	-2.14	-6	-71

* Table adopted from W.R Cline (2007) : see original table (Table 5.10,page 79) under " country -level agricultural impact estimates" in Global Warming and Agriculture ; Impact Estimates by Country.

Table 19.

Summary estimates by Cline (2007) for impact of global warming on world agricultural output potential by 2080s (percent)

Particulars	Without Carbon Fertilization	With Carbon Fertilization	Difference
Global output- Weighted	-15.9	-3.2	-12.7
Global population weighted	-18.2	-6	-12.2
Median by country	-23.6	-12.1	-11.5
Industrial countries	-6.3	7.7	-14
Developing countries	-21	-9.1	-11.9
Median	-25.8	-14.7	-11.1
Africa	-27.5	-16.6	-10.9
Asia	-19.3	-7.2	-12.1
Middle East North America	-21.2	-9.4	-11.8
Latin America	-24.3	-12.9	-11.4

Source : Cline (2007),original table no 7.1 (page 96) in Global Warming and Agriculture
Note : In spite of global warming the industrial countries stand to gain to the tune of 7.7% with CF

of most commodities sharply increased. The big question then would be; "why was the same not reflected into the FAOSTAT data base?", that formed the basis of the calculation's in Table 20. The difference between the lowest and highest values ranges from 98-626% (di-ammonium phosphate, 245%, rock phosphate 626%, potassium chloride 268%, triple superphosphate 284%, urea 98%) over a 5-year period. One most likely reason could be the large "masking" effect of huge subsidy to agriculture in the industrial countries, in particular (Birdsall and Clemens, 2003; Human Development Report, 2003). These issues have be an duly taken up for discussion elsewhere in the last part of the text (Sundaram, 2010).

Energy Use in Agriculture

Energy input-output data for major US crops: In the USA agriculture and food systems use each year 19% of the fossil fuel energy utilized in the country. The ready availability of cheap fossil fuels and farm machinery for a wide range of farm operations has replaced human labour to such an extent that use of farm labour to grow and harvest a hectare of row crop like corn and soybeans has gone down from 1200 hrs per hectare prior to the introduction of farm machinery to about 11 hrs presently (Pimentel, 2006); which would be approximately equal to the 150 mandays per hectare to 1.4 mandays per hectare. However, the "peak period" in the supply of oil and natural gas was reached in 2007 and in present post-peak oil scenario, crisis and price increase are posing serious rethinking on unbridled use of petroleum products specially in many oil deficit countries.

The data presented in the Table 22 for 10 US crops cultivated conventionally (through industrial agricultural practices) show considerable difference in the use of human labour, yield of crop, energy output by crops, the total energy input and the energy input-output ratio. Energy efficiency of a crop is manifested in a higher output–input ratio. As

Table 20.

Food and Agriculture : Producers price of products ($/ton) World data 2001-2010 (vide FAOSTAT data base; itemwise calculation)

Crop Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± SD	CV (%)
Rice	256	256	257	259	261	260	260	260	260	260	258.9±1.76	0.7
Wheat	121	120	121	122	121	121	123	120	126	125	122±1.45	1.2
Soybean	256	256	254	252	254	254	258	256	257	248	254.5±2.73	1.1
Maize	45	43	47	53	51	54	57	60	64	65	53.9±7.26	13.5
Potatoes	125	129	130	131	134	132	133	136	134	137	132.1±3.36	2.5
Vegetables	177	176	174	173	172	172	172	171	170	170	172.7±2.24	1.3
Tomatoes	364	364	364	364	364	365	365	365	366	366	364.7± 0.78	0.2
Grapes	572	572	572	572	572	572	572	572	572	572	572± 0	0
Apples	422	422	421	421	420	420	420	420	420	419	420.5± 0.92	0.2
Bananas	278	278	278	278	278	278	278	278	278	278	278± 0	0
Sugarcane	32	32	32	32	32	32	32	32	32	32	32± 0	0
Cotton lint	1429	1429	1429	1429	1429	1429	1429	1430	1429	1429	1429 ± 0	0
Cassava	95	95	95	95	95	95	96	97	97	0	95.6 ± 0.83	0.9
Livestock Sector												
Cow milk	298	297	297	299	300	300	301	300	300	299	299.1± 1.3	0.4
Buffalo milk	393	393	393	393	393	393	393	393	393	393	393± 0	0
Egg	829	829	829	829	829	829	829	829	829	829	829± 0	0
Cattle meat	2701	2701	2701	2701	2701	2701	2701	2701	2701	2701	2701± 0	0
Chicken	1424	1424	1429	1424	1424	1424	1424	1424	1424	1424	1424± 0	0
Pig meat	1537	1537	1537	1537	1537	1537	1537	1537	1537	1537	1537± 0	0
Sheep meat	2723	2723	2723	2723	2723	2723	2723	2723	2723	2723	2723± 0	0

such, corn and soybean with ratio of 5.1 and 4.6 respectively are more efficient than rice and wheat with 2.2 and 2.1 ratio respectively. Energy efficiency for production of potato is very low 1.3, nearly 4 units of energy is used to harvest one unit of tomato crop energy. On the other hand switch grass yields 14 units of energy with just 1 unit of energy input. An interesting finding is greater energy efficiency with organic farming that avoids the synthetic chemical fertilizers and pesticides.

In Table 23, the energy requirements for the production of livestock products are shown with data from Pimentel (2006) in retabulated and rearranged form. In view of fact that with growing economic prosperity, as in the OECD countries, consumption of livestock products is going up and presently in many developing countries the same trend is noticed particularly a significant increase in meat and dairy products consumption by a sizeable section of people who can afford the same. Although there could be some reasons to support that from the nutritional point of view, the basic question is the sustainability of the same in terms of feed and energy efficiency, and very importantly general economic affordability.

The ratio of kilocalorie feed energy to kcal of animal protein for lamb is 57. For a kg of mutton that much energy would come from 21 kg of grains and 30 kg of grass (forage). As such, for a kg of cattle meat 13 kg of grains and 30 kg forage would be necessary; for a kg of hen eggs (13.3 eggs, each of 75 gm weight) 11 kg of grains are required. The grain requirement for one kg of pig meat, turkey meat and chicken meat (broiler) are 5.9, 3.8 and 2.3 kg respectively. Dairy milk production requires 0.7 kg grains and 1 kg forage per kg of milk (energy input output ratio for milk protein, 14:1).

In the last two columns of Table 23 we have placed the world production of the aforesaid livestock products, and the estimated grain requirement (based on the requirement stated by Pimentel, 2006) to show that a large scale shift to livestock products, particularly meat would vastly increase the feed requirement and would definitely result in a shortfall of grains for direct human consumption specially in the developing countries. Only chicken meat with a with low energy requirement could be a viable option in countries like India where per capita availability of grains for use as food has been in a declining mode for several years.

Population Dynamics of the World and India over the Period of 2005-2015 to 2075-85

The world population (Table 24) will exceed 7 billion by the year 2015 and over 9 billion by the middle of the 21st century by which time the rate of population growth is expected to further slow down from 0.1 percent average annual growth rate to 0.05% growth rate. In 2085 the tentative population would be around ten and a half billion, a figure in conformity with United Nations “medium case” population projection. In the high population scenario, the projection is 14.7 billion in 2085. Even in the medium case, the increase in population from 2008 (6697 billion) to 2085 would be 57 percent, over 1.56 times (in the high case which we would hope rather unlikely, the increase would be 2.2 times over 2008; a doubling of population!).

So far India is concerned which is certainly overpopulated and already accounts for 17.2% of global population, the projected figure for population in the year 2085 would be 1.82 billion, a staggering figure, the highest for any country of the world at that point of time (the demographers are of the opinion that India will surpass China as the most populated country which may take place even by the middle of 21st century). In fact compared to 2008 population of 1140 million, the increase up to 2085 could

Table 21.

Primary commodity prices in International market (over a 5 - year period, 2005- 2009)

Food ,beverages, agric. Raw materials	2005	2006	2007	2008	2009	Mean ± SD	CV(%)	Diff H -L (%)
Food								
Fats and oils ($/mt)								
Coconut oil	560	542	778	978	610	694 ±165	24	80
Groundnut oil	963	867	1145	1704	995	1135± 298	26	97
Palm oil	383	427	661	758	574	561 ±140	25	98
Soybean	249	240	325	418	367	320 ±68	21	74
Soybean oil	495	535	747	1006	714	699 ±182	26	103
Grains ($/mt)								
Barley	86	104	146	160	108	121 ± 28	23	93
Maize	90	109	139	178	139	131 ± 30	23	98
Rice (Thailand)	260	272	277	520	467	319 ± 163	51	100
Sorghum	87	110	138	166	127	126 ± 27	21	91
Wheat, Canada	179	194	254	363	253	249 ± 65	26	103
Wheat, US, Red winter	138	172	216	261	188	195 ± 22	11	89
Other food								
Bananas, US ($/mt)	547	607	572	675	712	622 ± 62	10	30
Beef (cent/kg)	238	228	220	251	222	232 ± 11	5	5
Chicken meat (cents/kg)	135	124	133	136	144	134 ± 6	4	16
Oranges ($/mt)	794	741	810	885	764	799 ± 49	6	19
Shrimp, Mexico (cents/kg)	939	915	855	854	795	872 ± 51	6	18
Sugar, World (cents/kg)	20	29	19	23	34	25 ± 6	24	70
Beverages (cent/kg)								
Cocoa	140	142	165	206	243	179 ± 40	22	47
Coffee, arabica	230	225	231	246	267	240 ± 15	6	19
Coffee, robusta	101	133	162	189	138	144 ± 29	20	87
Tea (average of 3 auction)	150	168	172	193	229	182 ± 27	15	53
Agric. raw materials								
Cotton A index (cents/kg)	110	113	118	126	116	117 ± 5	4	15
Rubber, Singapore (kg)	135	186	192	207	161	176 ± 25	14	53
Tobacco ($/mt)	2553	2653	2808	2869	3523	2881 ± 340	12	38
Fertilisers ($/mt)								
Diammonium phosphate	224	233	366	773	272	374 ± 206	55	245
Phosphate rock	38	40	60	276	102	103 ± 89	86	626
Potassium chloride	144	156	170	456	530	291 ± 167	57	268
Triple superphosphate	183	180	287	703	216	314 ± 198	63	284
Urea	199	199	262	394	210	253 ± 74	29	98

Source : World Development Indicators, 2011 (basic/primary data) Diff H-L (%) : difference between highest and lowest prices of a commodity expressed as the percentage of the lowest.

Table 22.

A comparative study of the rate of return in calories (kcal energy output) vis-a -vis calories of fossil fuel or equivalent energy invested in production (kcal energy input) of major crops in the USA using mainly conventional agricultural technology with a couple of example of "organic agriculture" practices.

(Values in parentheses under yield of crops shows energy output per kg of crop)

(A). Comparison of energy input-output data of major US crops

Crops	Technology	Labours hrs/ha	Yield of crops Ton/ ha	Crop energy kcal x 10^3	Energy input kcal x 10^3	Output / input ratio
Corn	Conventional	12	7.4 (3.58)	26492	5,200	5.1
Soybean	Conventional	12	2.7 (3.60)	9720	2,100	4.6
Rice	Conventional	24	7.4 (3.60)	26522	11,838	2.2
Wheat	Conventional	7.8	2.7 (3.38)	9035	4,239	2.1
Potato	Conventional	35	40.7 (0.57)	23296	17,470	1.3
Cabbage	Conventional	60	27.3 (0.50)	13782	11,006	1.3
Orange	Conventional	210	46 (0.51)	23519	23,549	1. 0
Apple	Conventional	385	55 (0.56)	30660	50,195	0.61
Tomato	Conventional	363	41.8 (0.20)	8358	32,389	0.26
Switch Grass (Fodder)	Conventional	5	10 (4.0)	40000	2,775	14.4
(B). Comparison of Conventional and Organic system in corn and soybean						
Corn	Conventional	11.4	8.7 (3.58)	31132	7795	4.0
Corn	Organic	15	8.7 (3.58)	31132	5377	5.8
Soybean	Conventional	7.1	2.7 (3.6)	9605	3013	3.2
Soybean	Organic	9	2.7 (3.6)	9605	2501	3.8

Source : Pimentel (2006)

be nearly 60%, 1.6 times over 2008 population of the country, with nearly similar decline in growth rate as with the world and the percentage of Indians in the global population remaining more or less the same (17.3%).

Food and Nutritional Security in the Late 21st Century

Possible agricultural scenario around 2085

Projections on the basis of world agricultural situation in the first decade (2001 – 2010) of the 21st century : The data on world's top 20 agricultural commodities over a period of ten years (first decade of 21st century) have been analyzed itemwise in terms of annual increases in the first half-decade (2001 – 2005) and in the second half-decade (2006 – 2010). This has been done separately for all the crop and animal products (Table 25, 26). The percent changes between 2001 – 02, 2002 – 03, 2003 – 04 and 2004 – 05 have been calculated for the first half-decade. Similarly, for the second half-decade the percent annual changes (increase or decrease) between 2006 – 07, 2007 – 08, 2008 – 09 and 2009 – 10 have been

Table 23.

High energy requirement for products originating from livestocks; grains and forage inputs per kilogram of animal products produced and fossil fuel energy (or equivalent energy from other sources) inputs in kilocalories required to produce one kilogram of animal protein of different kinds. The last two columns show the data on world livestock production in 2010 (in million metric tonnes) and estimated requirements of grains(theoretical) for confined feeding (stall feeding) of animals as per requirements shown the table (see note below).

Livestock	Grains (kg)	Forage (kg)	kcal feed energy/ kcal animal protein (ratio)	World livestock production (mmt) 2010	Estimated grain requirement (mmt)
Lamb	21	30	57	8.6	181
Beef cattle	13	30	40	62.1	807
Eggs	11	0	39	63.6	700
Grass feed beef cattle	0	200	20	–	–
Pig meat	5.9	0	14	109.1	644
Dairy milk	0.7	1	14	720.5	504
Turkey meat	3.8	0	10	–	–
Chicken meat (broiler)	2.3	0	4	85.4	196
					Total = 3032
					World production = 2429

Note : In the USA and many other developed countries stall feeding of beef and dairy cattle and battery system of raising poultry are widely practiced, even in some developing countries with ever growing demand for animal products.The world grain production in 2010 was as follows for major grains (figures in mmt): rice 672,wheat 651,maize 844 and soybean 262 (total 2429 mmt). As such if major livestocks are raised commercially with confined feeding with food grains including wheat and rice ,besides maize and soybeans there would be an acute shortfall of grains for direct human consumption in the developing countries in particular.
Source of data on energetics : Pimentel (2006), data in the last two collumns are estimations from FOSTAT data base.

calculated. The individual annual changes over 5 years have been averaged to get mean half-decade values for each commodity to eventually evaluate the extent of difference between the two half-decades. It is to be noted that the annual change between 2005 – 2006 could not be accommodated in the half-decadal averages but the same was included in getting the full decadal average changes. Over the full decade the increases in the two major food grains rice and wheat have been 1.52 and 1.30 percent respectively; in case of potatoes it is 1.26%, in grapes 1.16% and for vegetables a small increase of 0.58% only. Satisfactory increases over the decade have been recorded with bananas (4.78%), soybeans (4.52%), maize (3.68%), tomatoes (3.52%) and sugarcane (3.37%). However, a comparison of the half-decades within the decade i.e., 2006 – 10 and 2001 – 05, reveals the decline in the rate of increase in most cases, and specifically a negative trend with cotton lint (-0.8% in 2006 – 10) and vegetables (-0.4%). Overall rate of increase in the crop sector was 2.90% in the first-half of the decade that fell to 2.30% in the second half-decade, falling by 0.60% the change in percentage terms is quite appreciable and the overall net change is -20.7% (i.e. -0.60/ 2.90×100 = -20.69).

In the livestock sector (a sector that is dependent on the crop sector for feed grains and fodder there has been a manifestation of the aforesaid declining trend specifically on the important commodity, cattle meat production. The rate of increase in the milk subsector with buffalo milk converted to cow milk equivalent (CME) values, was 2.24% in the full decade, the change was 2.40% in the first half-decade (2001 – 2005) but fell to 2.01% in the second-half of the decade (2006 – 2010). Chicken meat showed a steady rise and in the second half-decade the average rate of annual change was 4.30% (Table 26). Hen eggs showed a decadal increase of 2.21%, there was a marginal increase in the second-half of the decade. In case of cattle meat, there was a considerable fall between the first-half and second-half of the decade (from 1.50% to 0.18%). Pigmeat retained a moderate rate of increase of around 2% throughout the first decade. However, as with the crop sector,

Table 24.

Population projection of the world and India over the period 2005 - 2015 to 2075 - 85

(Population in millions in the middle of year, July 1 of the year)

Year	World		India	
	Avarage annual growth rate (%) over a 10 year period	Population (million)	Average annual growth rate (%) over a 10 year period	Population (million)
2015	1.10 (2005 - 15)	7241	1.30 (2005 - 15)	1246
2025	0.90 (2015 - 25)	7923	1.10 (2015 - 25)	1391
2035	0.70 (2025 - 35)	8498	0.90 (2025 - 35)	1522
2045	0.60 (2035 - 45)	9023	0.70 (2035 - 45)	1632
2055	0.50 (2045 - 55)	9486	0.50 (2045 - 55)	1716
2065	0.45 (2055 - 65)	9922	0.30 (2055 - 65)	1768
2075	0.35 (2065 - 75)	10276	0.20 (2065 - 75)	1804
2085	0.25 (2075 - 85)	10536	0.10 (2075 - 85)	1822

Note : (1) **Total population :** De facto population in a country, area or region as of July estimated by the formula.

$pn = p_o e^{rt}$

Where pn = population in a given time(year)

po = Initial population

e = exponential

r = average annual exponential growth rate

.=e [ln(pn/po) / t] - 1

t = time, (years)

(2) As per World Development Indicators (Chapter 21 : Population Dynamics, the 2008 and 2015 populations for the world are 6697.3 and 7241.2 million respectively (r = 0.011 i.e. 1.1% for the period 2008-15); the same for India are 1140.0 and 1246.9 million respectively (r = 0.013 i.e.1.3% for the period 2008 - 15) the subsequent rates are based on perceptions by the present authors from various other sources. There is, however, a broad similarity in global population in median case projections of the United Nations for 2085 and that worked out in the table above (namely 10.52 billion in the UN data and 10.54 billion here).

Table 25.

World Production of Agricultural Commodities in the Crop Sector (CS) in the first decade of the 21st century along with itemwise annual changes (%) in the rate of production

[Production in million metric tonnes (mmt),annual changes(%) in rate of production in percent (%)]

Crop Sector	Particulars	Mean 2001-10	Mean 2001-05	Mean 2006-10
Rice	Production in mmt	634± 41	600± 21	669±18
	Annual change %	1.52	1.48	1.33
Wheat	Production in mmt	622±41	597±29	647±35
	Annual change %	1.3	1.75	2.13
Soybean	Production in mmt	213±24	194±14	232± 16
	Annual change %	4.52	4.73	4.53
Maize	Production in mmt	729±84	661±50	797±49
	Annual change %	3.68	3.93	4.63
Potato	Production in mmt	322± 9	320 ± 9	333 ± 9
	Annual change %	1.26	2.83	1.48
Vegetables	Production in mmt	239±8	231±4	246±3
	Annual change %	0.58	0.63	-0.4
Tomatoes	Production in mmt	131±13	120±8	142±8
	Annual change %	3.52	4.48	3.1
Grapes	Production in mmt	659± 2.4	64.5±2.6	67.3±1.0
	Annual change %	1.16	2.25	0.38
Apples	Production in mmt	63.5±4.9	59.4±2.7	67.7±2.4
	Annual change %	2.22	2.08	2.2
Bananas	Production in mmt	82.4±11.9	71.7±4.6	93.0±6.0
	Annual change %	4.78	4.3	4.9
Mangoes etc	Production in mmt	–	–	38.7
	Annual change %	–	–	–
Sugarcane	Production in mmt	1477±169	1329±36	1626±108
	Annual change %	3.37	1.1	4.6
Cotton lint	Production in mmt	22.5± 2.2	21.7± 2.4	23.5± 1.5
	Annual change %	1.74	4.6	-0.78
Cassava	Production in mmt	209±195	193± 9	229 ± 4
	Annual change %	3.26	3.13	1.63

there has been a noticeable decline of the rate of increase in all products except chicken meat and egg. The overall rate of increase of livestock products has been 2.20% in the first-half of the decade (2001 – 05) against 1.90% in the second half-decade (2006 – 2010), a decline of 0.30% which in terms of net percentage of decrease would a 13.6% fall from first-half to second-half of the decade. The results substantiate the fact that despite small increases of production

Table 26.

World Production of Agricultural Commodities in the Livestock Sector (LS) in the first decade of the 21st century along with itemwise annual changes (%) in the rate of production. Other details same as in Table 25

[Production in million metric tonnes (mmt),annual changes (%) in rate of production in percent (%)]

Livestock Sector	Particulars	Mean 2001-10	Mean 2001-05	Mean 2006-10
*Cow milk	Production in mmt	555±43	617±20	693±19
	Annual change %	2.24	2.4	2.01
*Hen eggs	Production in mmt	57.8±3.8	54.5±1.5	61.2±2.0
	Annual change %	2.21	2.1	2.3
Cattle meat	Production in mmt	59.7±2.5	57.6±1.5	61.9±0.7
	Annual change %	1.1	1.5	0.18
Chicken meat	Production in mmt	72.4±8.0	65.3±3.3	79.3±4.7
	Annual change %	3.88	3.8	4.3
Pig meat	Production in mmt	99.9±5.3	95.7±3.1	104.1±3.2
	Annual change %	2.01	2.4	1.9
Sheep meat	Production in mmt	8.23±0.34	7.9±0.11	8.55±0.1
	Annual change %	1.08	1	0.7
Composite (Meat total)	Production in mmt	240±16	227±8	254±8
	Annual change %	2.36	2.7	2.1
Mutton Equivalent	Production in mmt	162±10	153±5	170±4
	Annual change %	2.1	2.5	1.6
Chicken meat equiv.	Production in mmt	309± 19	293± 10	326± 8
	Annual change %	2.11	2.3	1.7

in terms of metric tonnes, the rate of increase estimated as annual growth rate has started to decline.

Yield projections

If the aforesaid decline in yield over the half-decade periods continues in the same manner over the time span upto 2085 (i.e. 75 years i.e. 7.5 decades or 15 half-decades), then for the crop sector showing 0.60% decline in a half-decadal period (5 years) an approximately 9% fall would be expected by 2085. If the decline is exponential the fall by late 2080's would be much higher for the crop sector and the same would be manifested on the livestock sector. The crops are autotrophs which are endowed with the capacity to carry out photosynthesis and directly and indirectly the chlorophyllous plants support the survival of heterotrophic animals including livestocks that depend greatly on feed grains and a wide range crop residues and byproducts. Anything detrimental to the plants would adversely affect all other organisms.

The livestock sector of the world producing six commodities (vide Table 26, dealing with top 20 agricultural commodities), collectively valued at over 51.2% of the global agricultural output also showed a change in average annual growth rate, and over the 7.5 decades till 1985, a 0.30% decline per half-decade, around 4.5% fall in output may occur; however, if the decline is exponential it could be still higher.

Indian scenario

The production of the most important crop of India, rice, has virtually reached a plateau with a decadal average annual rate of change of -0.82% (Table 27). The first-half decade of the present century (2001 – 2005) showed an annual increase of 1.18% but subsequently in the second half-decade (2005 – 2010), the annual rate of increase averaged -3.30%; the difference between the two periods amounting to -2.12% which is indeed a very uncomfortable situation. The other major grain crop wheat did not show any increase in the first half-decade, rather a small decrease (-0.05%) in rate of change which was compensated in the second half-decade, giving an increase of 3.90% (the decadal average increase being 1.84%). The two grains together showed an average increase of 1.13% in the first half-decade and 0.60% in the second half-decade showing a half-decadal change of 0.53%. If the same is projected for 2085, a simple arithmetical extension would show a steady decline in output leading ultimately to a progressively negative production scenario for the two major grains.

The data for many of the crops of the country are characterized by ups and downs (with exceptionally high coefficients of variation) attributable to fluctuations in monsoon rainfall pattern over the years and with the passage of time the erratic behavior of the monsoon is increasing.

The livestock sector in India dominated by cow and buffalo milk (converted to cow milk equivalent, CME, values) has made India the biggest milk producing country in the world now (although per capita availability is low because of the huge population of the country). The decadal increase (2001 – 2010) averaged 4% (Table 28), only second to egg (5.0%); in the second half of the decade the average rate of annual increase in production of chicken meat has been noteworthy (8.9% but excluding 2006 – 07, also no production data in first half of the decade except for the year 2002). Overall it may be said that feed grain based livestock production on a large scale would be very difficult in India; only way is the effective planning of crop residue based management practices (giving proper consideration to the question of using the same as kitchen fuels in the villages and other uses) supplemented with oilcakes, forages, etc). The rise in chicken meat production in recent years is mainly due to its low feed energy requirement and relatively more affordable price but feed grain deficiency would be a major constraint in the future (see Table 29; also see Table 23).

Global Yield Projections till 2085 and probable Demand-Supply Situations

Grain production in a country (with a few exceptions) particularly per capita availability from domestic production is the most reliable measure of food sovereignty and nutritional security. Although botanically most grains are produced from plants belonging to the grass family such as rice, wheat, barley, oats, maize, jowar, bajra, sorghum and a range of other millets, there are some that belong to other families such as the leguminous soybeans, buckwheat (family Polygonaceae) etc. and are used mostly as food or feed grains. The grains primarily serve as carbohydrate-rich energy providers (soybean, however, is rich in protein and oil) but some of the millets are also nutritionally rich. In any case, besides serving as human food, the livestock sector which is a major component of agriculture is very much dependent on grains as essential feed staff. There is in fact great demands of grains for human food, livestock feed and use of grains like maize

Table 27.

Production in India of Agricultural Commodities in the Crop Sector (CS) in the first decade of the 21st century along with itemwise annual changes (%) in the rate of production

[Production in million metric tonnes(mmt),annual changes(%)in rate of production in percent (%)]

Crops	Particulars	Mean 2001-10	Mean 2001-05	Mean 2006-10
Rice	Production in mmt	133.0±22.0	128.±11.7	137.4±9.8
	Annual change %	-0.82	1.18	-3.3
Wheat	Production in mmt	73.4±5.0	69.7±2.4	77.0±4.2
	Annual change %	1.8	-0.05	3.9
Sugarcane	Production in mmt	289.9±37.4	270.3±28.7	309.5±34.7
	Annual change %	0.29	-5.1	1.1
Cotton lint	Production in mmt	3.33±1.23	2.29±0.63	4.36±0.70
	Annual change %	18.9	19.4	17.5
Soybeans	Production in mmt	9.0±1.33	7.66±0.58	9.96±0.75
	Annual change %	4.5	4.1	5.3
Vegetables	Production in mmt	42.2±8.7	36.1±7.1	47.2±3.7
	Annual change %	3.9	-14.4	6.9
Potatoes	Production in mmt	29.0±4.7	25.3±2.6	32.7±3.2
	Annual change %	6.3	7.2	6.2
Tomatoes	Production in mmt	9.3±1.6	7.9±0.6	10.7±0.8
	Annual change %	4.7	5.1	5.2
Pulses	Production in mmt	6.25±2.53	4.19±1.31	7.82±2.64
	Annual change %			
Fresh fruit	Production in mmt	39.0±8.9	31.9±2.7	46.1±7.1
	Annual change %	8.3	5.8	10.3

for production of ethanol (ethyl alcohol) a replacement for petrofuels that is in short supply. Livestock products are nutritionally rich because of transformation of feed grains and forage to animal proteins and fats. From the energetic point of view; however, conversion of feed to milk, meat, egg, etc. is highly energy intensive and as such expensive for the general consumers especially of the developing countries. The issue has been dealt with in more details elsewhere (Table 23).

The important countries in grain production (wheat equivalent values, mmt) in 2010 (Table 29) are as follows : China (617 mmt), USA (427 mmt), India (331 mmt), Brazil (195 mmt), Indonesia (148 mmt), Argentina (134 mmt), Bangladesh (105 mmt), Vietnam (83 mmt) and Thailand (68 mmt). In terms of wheat equivalent (equivalence based on price) grain availability in kg per capita per year the ranking is different and Argentina with 3285 kg per person is ranked highest followed by Myanmar (1383 kg) and USA (1380 kg), Cambodia (1183 kg), Canada (1118 kg), Thailand (1048 kg), Australia (1033 kg), Brazil (981 kg), Vietnam (917 kg) and France (732 kg). Rice producing countries like Myanmar, Cambodia, Thailand, Vietnam are at an advantage because price of rice is twice that of wheat, as such wheat equivalence has doubled the value based estimates. Nevertheless, rice is basically a human food but the others particularly maize is primarily an animal feed and in USA nearly half of corn is currently diverted to subsidized bioethanol production.

In view of the great importance of grains in agriculture, Cline (2007) took into consideration the average annual increase in yields per hectare (% increase) of the 4 major grains, wheat, rice, maize and soybeans from major producing countries (7 countries Argentina, Australia, Canada, China, France, India, USA for wheat; 6 countries for rice namely, Bangladesh, China, India, Indonesia, USA and Vietnam; maize for 5 countries, Argentina, Brazil, China, Mexico, USA; and 4 countries for soybean, Argentina, Brazil, India and USA) to get firstly the weighted average increase in yields per hectare for the four crops and then based on their wheat equivalent weights the average annual percent increases in yield over the periods 1961 – 83 and 1984 – 2005 (see summary table, Table 30). The mean values for the two periods have been 2.81% (between 1961 – 1983) and 1.57% (for the period 1984 – 2005). With the latter value, 1.57% in 2005 the expansion factor (after 80 years) denoted as $l_q = (1.0157)^{80} = 3.48$.

We have used the above noted rate of change (1.57%) which is free from absolute quantities of products to get an estimate of the annual rate

Table 28.

Production in India of livestock sector (LS) commodities in the first decade of the 21st century along with itemwise annual changes (%) in the rate of production

[Production in million metric tonnes (mmt),annual changes (%) in rate of production in percent (%)]

Crops	Particulars	Mean 2001-10	Mean 2001-05	Mean 2006-10
Milk(CME)	Production in mmt	108±13.3	95.7±3.1	120.3±3.1
	Annual change %	4.1	0.45	4.1
Egg (Hen)	Production in mmt	2.73±0.44	2.34±0.17	3.12±0.22
	Annual change %	5.3	4.7	5
Cattle meat	Production in mmt	1.0±0.05	0.96±0.01	1.04±0.03
	Annual change %	1.3	0.3	2.2
Chicken meat	Production in mmt	1.79±0.40	1.09±0	1.96±0.23
	Annual change %		1	8.9
Buffalo meat	Production in mmt	1.37±0.07	1.31±0.03	1.43±0.03
	Annual change %	0.8	1.8	1.4
Composite(Meat total)	Production in mmt	4.16±1.03	3.37±0.42	4.44±0.87
	Annual change %	12.5	5.1	22.6
Mutton Equivalent	Production in mmt	3.29±0.58	2.83±0.21	3.48±0.48
	Annual change %	7	2.3	13.1
Chicken equivalent	Production in mmt	6.28±1.11	5.40±0.39	6.64±0.91
	Annual change %	7	2.3	13

Table 29.

Grain production in the 33 selected countries in 2010 (million metric tonnes, mmt), composite values as well as rice and wheat equivalent values (also per capita availability in Wheat equivalence)

Countries	Rice (mmt)	Wheat (mmt)	Maize (mmt)	Soybean (mmt)	Total grains (comosite, mmt)	Rice equivalent values (mmt)	Wheat equvalent values (mmt)	Per capita availability as wheat equvalent (kg/person /year)
Argentina	1.2	14.9	22.7	52.7	91.5	64.3	133.7	3285
Australia	0	22.1	0	0	22.1	10.6	22. 0	1033
Bangladesh	49.9	0.9	0	0	50.8	49.8	104.5	629
Brazil	11.3	6	56.1	68.5	141.9	93.6	194.6	981
Cambodia	8.2	0	1.4	0.2	9.8	8.7	18.1	1183
Cameroon	0	0	1.7	0	1.7	0.4	0.8	41
Canada	0	23.2	11.7	4.3	39.2	18.2	37.8	1118
China	197.2	115.1	177.5	0	489.8	296.9	617.3	456
Colombia	2.4	0	0	0	2.4	2.4	5. 0	105
Cuba	0.5	0	0	0	0.5	0.5	1. 0	88
Egypt	4.3	7.2	0	0	11.5	7.8	16.2	204
France	0	38.2	14. 0	0	52. 0	21.9	45.5	732
Germany	0	22.4	0	0	22.4	10.8	22.4	272
India	120.6	80.7	0	0	201.3	159.4	331.4	283
Indonesia	66.4	0	18.4	0	84.8	71	147.6	618
Italy	1.6	6.9	0	0	8.5	4.9	10.2	173
Japan	10.6	0	0	0	10.6	10.6	22. 0	173
Kenya	0	0.5	3.2	0	3.7	0.34	2.2	54
Madagascar	4.7	0	0.4	0	5.1	4.8	10. 0	472
Mexico	0	3.7	23.3	0	27. 0	7.6	15.8	144
Myanmar	33.2	0	0	0	33.2	33.2	69. 0	1383
Netherlands	0	0	0	0	0	0	0	0
Pakistan	7.2	23.3	3.3	0	33.8	19.2	39.9	229
Philippines	15.8	0	6.4	0	22.2	17.4	36.2	391
Russian Fed.	1.1	41.5	0	0	42.6	21.1	43.9	313
South Africa	0	1.5	13.1	0.6	15.2	4.6	9.6	215
Spain	0.9	0	0	0	0.9	0.9	1.9	39
Sri Lanka	4.3	0	0	0	4.3	4.3	8.9	456
Thailand	31.6	0	4.5	0	36.1	32.7	68. 0	1048
United Kingdom	0	14.7	0	0	14.7	7.1	14.8	241
United States	11. 0	60.1	316.2	90.6	477.9	205.4	427. 0	1380
Vietnam	40. 0	0	0	0	40. 0	40	83.2	917
Zambia	0.1	0.2	0	2.8	3.1	2.9	6. 0	476
WORLD	672	650.9	844.4	261.6	2428.9	1445.7	3005.6	437

of increase by comparing the same with the annual increase during the period 1961 – 2083. The difference for wheat equivalent averages between the first phase (1961 – 1983) and the second phase (1983 – 2005), over a period of 22 years has been -1.24 which is equal to -0.05636 per year, accepting this rate of decline over five years; the value in 2010 would be arithmetically 1.57- (0.05636×5) = 1.288%. As such, the expansion factor by 2085 would be : $l_q = (1.01288)^{75} = 2.611$. It needs to be noted that Cline (2007) estimated the secular increase in yield up to 2085; if however, small decreases over half-decades or decades are used in the estimation, the same declining trend already set in (-0.05636% per year) would give the following results starting first with a half-decadal change then through full decadal changes till 2080 and ending with half-decadal change up to 2085 e.g. year 2005 : +1.570%, 2010 : +1.288%, 2020 : +0.724%, 2030 : +0.161%, 2040 : –0.403%, 2050 : –0.966%, 2060 : –1.530%, 2070 : –2.094%, 2080 : –2.657%, 2085 : –2.939%. Compared to a secular conservative approach through retention of the same rate of annual change over a long period in a gradually declining productivity scenario, the incorporation of discrete short term changes, as in geometric growth rate calculations, would most likely be a more pragmatic approximation. Of course it would not be as secular as that of Cline (2007) and in any case it would be difficult to isolate and quantitate the negative effects of climate change and suspected technology-fatigue.

We have summarized in Table 30 the revised estimates of expansion factors vis-à-vis that of the original estimates by Cline (2007).

Arguably, if Cline undertook the work around this time he would have arrived at a similar situation and anyone doing the same after a decade or so would most likely face much higher negative effects simply because initial rates would be progressively lower with the passage of time in the post-green revolution declining phase most likely accentuated by adverse impacts of global climate change. As indicated earlier it would be difficult to isolate and quantitate the individual role of the yield-depressing factors particularly in view of likely positive and negative interactions. The positive role of carbon fertilization and particularly the extent of benefit with increasing CO_2 levels in the atmosphere is as yet a debatable issue. The growing global shortage of economically recoverable phosphates (according to Roberts and Stewart, 2002 economically recoverable phosphorus in the world would be available for another three decades only, global potassium may, however last another 100 years or so) would certainly be a limiting factor in industrial agriculture where recycling of nutrients is a long forgotten subject. The nutrients ultimately lost to the seas and oceans, though still in the planet, are practically lost for good.

Strategies for Overcoming Food Insecurity, Hunger and Poverty

As shown in the discussion on mismatch between supply and demand for agricultural products, a shortage of food, feed and other agricultural products in the World is almost certain to occur in the late 2080s. In fact the decline has already started and with the passage of time would be progressively amplified. The major reason of the increasing demand is attributable to population expansion and increasing income (albeit inequitably) that would fuel greater consumption of agricultural products through enhanced purchasing power. While increase in income would be welcome, that in case of population must be avoided by all legitimate means. A bottom-up approach, initiated by the society itself, as in the West, where many countries have entered the phase

Table 30.

Demand-supply scenario for a rising global population at around 2085

Cline's original estimates from 2005 to 2085	An initial yield rate modified revised estimates for 2010 to 2085
(A) Demand from population growth	(medium growth scenario)
Population in 2004: 6460 million; 2085: 10,520 million	2010: 6846 million; 2085: 10,536 million
Population expansion factor (λ_N) λ_N = 10520/6460 = 1.628	λ_N = 10536/6846 = 1.539
(B) Demand from rising income at about 1% annual rise in income with income elasticity of food = 0.612	= 0.612 (same income elasticity)
In 2085 $\lambda_N = (1.00612)^{80}$ = 1.629	$\lambda_y = (1.00612)^{75}$ = 1.580
Total demand $\lambda^D = \lambda_N \times \lambda_y$ = 1.628 × 1.629 = 2.652	$\lambda^D = \lambda_N \times \lambda_y$ = 1.539 × 1.580 = 2.432
(C) Supply through increase in yield over the years up to 2085	
Over 2005 – 85, $\lambda_q = (1.0157)^{80}$ = 3.477 annual rate = 1.57%	Over 2010 – 85, $l_q = (1.01288)^{75}$ = 2.611 annual rate = 1.288%
(D) Supply reduction through diversion of land for other purposes such as bioethanol production, etc.	
λ_B = 0.7	λ_B = 0.7 (same 30% diversion of land)
Total supply factor = $\lambda^S = \lambda_q \times \lambda_B$ = 3.477 × 0.7 = 2.434	$\lambda^S = \lambda_q \times \lambda_B$ = 2.611 × 0.7 = 1.828
Short fall in supply vis-à-vis demand = $\lambda^S - \lambda^D$ = 2.434 – 2.652 = -0.218 = -8.96% (approx. -9.0%)	$\lambda^S - \lambda^D$ = 1.828 – 2.432 = -0.604 = -33.04% (approx. -33%)

of negative population growth, needs to be promoted urgently. The seriousness of the problem in poor developing countries need all possible cooperation between politicians, sociologists, religious leaders and demographers with utmost earnestness to tackle unbridled population growth. Equally important is the urgent necessity to come to a global consensus on mitigation of greenhouse gases despite repeated failures of such efforts. It is absolutely essential for the proper functioning of the ecosystems that are crucial to the survival of not only the mankind but the biosphere as well.

According to the United Nations and World Bank sponsored International Assessment of Agricultural Science and Technology for Development (IAASTD, 2008) agricultural policies need to be developed for emission reductions as well as adaptation to climate change; these should be closer to carbon neutral, minimize trace gas emissions and reduce natural capital degradation. It would be most pertinent to very briefly recall the views of IAASTD on impacts of climate change on different sectors of agriculture and options and strategies to effectively counter them.

IAASTD on climate change impacts on various subsectors of agriculture

i) Although the highest emissions of greenhouse gases are associated with the most intensive farming systems and the least for subsistence type rainfed agriculture as in sub-Saharan Africa yet the latter is amongst the most vulnerable regions to the impact of climate change due to multiple stresses.

ii) Changes in land use have adversely affected the net ability of ecosystems to sequester carbon from the atmosphere. The replacement of carbon-rich grasslands and forests by crops in the temperate zone would result in much lower carbon sequestration. Although in the northern hemisphere there is a slow increase in forests, the overall advantage is being lost due to increased deforestation in the tropics and subtropics. Forest replacement by perennial oil palm plantations, as in southeast Asia, may be advantageous for carbon sequestration but cannot compensate for the loss of biodiversity and its potential advantages. Some vulnerable natural pools of carbon such as peat lands are likely to become sources of CO_2 emission due to climate change.

iii) Livestock holders would suffer in various ways as animals are very sensitive to heat stress and drought; they require reliable resource of water and pasture. Further incidences of infectious and vector-borne diseases, to which livestock are vulnerable, would considerably increase globally with climate change. Incidentally, 75 percent of emerging diseases are zoonotic (diseases that are transmitted between animals and humans) and the indirect impact on agriculture would be considerable especially in the human labour intensive developing countries.

iv) Regarding the future impacts of climate change on crop and tree yields, fisheries, forestry and livestock, a wide region-to-region variation would be expected. Local biomes and terrestrial ecosystems will be adversely impacted. As there is little doubt that climate change will impact regional patterns of temperature and precipitation, climate projections are as yet unable to elucidate exactly when, where and how the changes will be experienced.

v) Global climate change is expected to alter marine and fresh water ecosystems and habitats. Rising sea levels will alter coastal habitats and their future productivity, threatening some of the most productive fishing areas in the world. Altered ocean currents consequent upon temperature rise will bring about changes in distribution and ranges of marine animals including fish populations. Sea level rise leading to salt water intrusion will result in reduced agricultural productivity in many coastal areas. Secretion of calcareous shells or skeletons by corals, molluscs etc., so essential for their survival, will be disrupted because of acidification of sea water due to excess carbon dioxide dissolving in water. All these will have a serious impact on marine ecosystems and vital food webs, even affecting the diversity of fish species in marine as well as fresh water lakes and rivers.

vi) Climate change is already affecting and will continue to affect the geographic range of many animal and plant pests, disease vectors and a wide variety of invasive species that will inhabit new ecological niches with negative impact on agricultural activities through their effect on the health of farmers and functioning of ecosystems, especially in the developing countries. An increase in temperature and precipitation would be conducive to the expansion of a wide range of vector transmitted diseases with the strong possibility of those being established outside their present range and also at higher elevations. Increased irrigation to counter water scarcity may increase the incidence of water related diseases including malaria. Seasonal weather changes (short-term version of climate change) as well as long-term climate change will strongly influence the incidence of pests and diseases. Conditions favourable for pests and diseases such as higher winter temperature (implying reduced winter-kill) and higher rainfall (and humidity) may encourage new pest introductions that would alter pest-predator-parasite dynamics through changes in growth and development rates, number of generations produced per year, the severity and density of populations, the pest virulence to host plants or the extent of susceptibility of the host to the pest. Changing weather patterns also increase crop vulnerability to pests, weeds and invasive plants, thus decreasing yields and increasing pesticide applications. Increased temperatures are likely to facilitate range expansion of some highly damaging weeds, which are usually limited by cool temperatures.

vii) IAASTD has cautioned about the serious potential for future conflict and possible violent clashes over habitable land and natural resources, such as fresh water, as a result of climate change that would seriously jeopardize food security and poverty reduction. Annually an estimated 25 million people flee from weather related disasters, this number is projected to increase to about 200 million by 2050 with semi-arid ecosystems expected to be the most vulnerable to the adverse impacts of climate change. IAASTD further points out that climate change, combined with other socioeconomic stresses could alter the regional distribution of hunger and malnutrition particularly in the poor developing countries of the world.

Options for Action to Meet Climate Change Impacts (vide IAASTD)

Climate change is not merely an environmental issue; it encompasses broader issues such as sustainable development and livelihood security that involves equitable access to resources and appropriate technologies as well as support systems and mechanisms to cope with risks.

Agricultural policies need to be developed for emission reductions as well as adaptation to climate change; these should be closer to carbon neutral, minimize trace gas emissions and reduce natural capital degradation. The focus should be on emission reduction in agriculture and forestry, production of food with greater input efficiency and less GHG emissions, and how best agriculture, agroforesty and forestry can adapt to give local conditions. For all these a revised and retooled Agricultural Knowledge, Science and Technology (AKST) would be required for meeting the challenges of energy efficient farming systems development as well as more comprehensive cost-benefit analysis than those now available. Further interconnected issues such as the negative effects of land use changes on biodiversity and on land degradation need to be addressed in order to exploit the synergies between the goals of UN conventions on biodiversity, and desertification and climate change.

Complementary nature of mitigation and adaptation strategies : In view of the fact that the effects of reduced emission (mitigation) to avoid temperature rise will not be manifested soon, and may even be delayed for several decades, due to the inertia of climate system (time lag between emission of GHGs and temperature rise), adaptation will be important in coping with the early impacts. In fact adaptation will be essential to meet the challenge of impacts on agriculture to which it is already committed in near or distant future. Mitigation would be the best recourse at all times and it will be the only option when unmitigated climate change exceeds the adaptive capacity of the existing agricultural systems. Mitigation options include a range of approaches such as lower rates of agricultural expansion into natural habitats, afforestation, reforestation, agroforestry and restoration of underutilized or degraded land, carbon sequestration in agricultural soils, appropriate application of nitrogenous inputs, effective manure management and use of feed that increases livestock digestive efficiency.

Policy options include financial incentives to maintain and increase forest area through reduced deforestation and degradation and improved management to increase the production of renewable energy sources.

Local, national and regional agricultural development frameworks will have to take into account the trade-offs between the need for promoting higher yields and the need for the maintenance and enhancement of environmental services that support agriculture.

Climate change adaptation options

Two adaptation options have been recognized, namely autonomous adaptation and planned adaptation. Autonomous adaptation does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market and welfare changes in human systems. Planned adaptation is the result of a deliberate policy decision and involves implementation of existing knowledge and technology and increasing the adaptive capacity through improved policies and investments in new technologies and infrastructure for more effective adaptation activities.

Autonomous adaptation options: These are largely extensions or intensifications of existing risk management or production enhancement activities as given below :

i) Changing varieties/species to fit more appropriately to the changed climatic conditions.
ii) Changing time of irrigation and adjusting nutrient management.
iii) Applying water conserving technologies and promoting agro-biodiversity for increased resilience of the agricultural systems.
iv) Altering timing or location of cropping activities, and diversification of agriculture.

Planned adaptations: These include the following:

i) Implementation of specific policies aimed at reducing poverty and increasing livelihood security.
ii) Provision of infrastructure to support integrated spatial planning and to generate and disseminate new knowledge and technologies.

iii) Development of management practices tailored to anticipate changes in climate.

According to IAASTD the aforesaid strategies are in fact, examples of the mainstreaming of climate change adaptation into policies intended to enhance broad resilience.

The effectiveness of the adaptation strategies is likely to vary significantly between and within regions depending on the impacts and adaptive capacity of regions or areas that may differ very much infrastructurally and socioeconomically.

For climate predictions to meet the needs of agriculture it would be necessary to increase observational networks in the most vulnerable areas along with further improvements in forecast accuracy along with the integration of seasonal prediction with information at shorter as well as longer time scales.

Climate change mitigation options (as suggested by IAASTD)

i) Reducing emissions of carbon dioxide, deforestation and forest degradation that would include policy measures to prevent deforestation, improving forest management, forest fire management, improving silvicultural practices, promoting afforestation and reforestation to increase carbon storage in forests.

ii) Improving soil carbon retention by promoting global biodiversity and associated ecosystem services (valued at US $1,542 billion annually by IAASTD), as a strategy for climate change mitigation and adaptation, and improving management of residues using zero or reduced tillage, growing legumes in crop rotation, reducing fallow periods and converting marginal lands into woodlots.

iii) Reducing levels of methane emission in livestock production by improving animal diets and using feed additives to increase food conversion efficiency by reducing enteric fermentation and consequent methane emissions, aerating manure before composting, recycling agricultural and forestry residues to produce biogas or biofuels.

iv) Giving support to low input farming in agriculture that relies on renewable sources of energy.

v) Policy options should include giving financial incentives to increase forest area, reduce deforestation and for enhancing the production of renewable energy source.

IAASTD cautions that efforts towards emission reduction of a particular GHG should not encourage GHG emission from other potential sources; often reduction in methane emission may lead to greater N_2O emission through changes in soil nitrogen dynamics; conservation tillage for carbon sequestration may result in elevated N_2O emissions through increased use of agrochemicals and accelerated denitrification in soils.

Climate change regimes: Although IAASTD (2008) regarded the Kyoto Protocol as one representing the highest level of International consensus to address climate change, its report pointed out that mitigation options for agriculture has, however, not been well covered under the Protocol. Incidentally, Kyoto Protocol itself has been effectively shelved in the Copenhagen summit meeting of the heads of states in December, 2009 because of intervention by USA and several other countries.

IAASTD is of the opinion that to take full advantage of the opportunities offered by agriculture and forestry sectors, a long term (30-50 years) comprehensive and regulatory framework would be necessary. Within such a framework, a modified Clean Development

Mechanism (CDM) with a comprehensive set of eligible agricultural mitigation activities could help in meeting the development and sustainability goals. Such activities should include afforestation and reforestation, avoiding deforestation, using a national sectoral approach rather than a project approach allowing for policy interventions, and a wide range of agricultural practices (that includes organic agriculture) for development and long term sustainability goals. The future of conservation agriculture in the current format with lot of emphasis on agrochemicals, particularly toxic herbicides is, however, doubtful.

GHG mitigation and energy saving in organic farming

Although IPCC (2007) pointed out the significant contribution of conventional industrial agriculture along with deforestation on GHG emission (together 30.9 percent) and global warming, it was IAASTD (2008) that indicated the possibility of countering the same by ecologically sustainable natural resource management based agriculture.

Mae-Wan Ho (2008) in a press release by the Institute of Science in Society, UK (ISIS) reestimated the contribution of industrial agriculture and food systems to global anthropogenic greenhouse gas emissions and produced an estimate of 34 percent GHG emission as the overall agriculture and food related contribution.

Further, there is a large scope for reversing the damages of the current agriculture and faulty food systems by organic agriculture and localized food systems that besides effectively mitigating the whole of the agricultural GHG emission would save energy equal (or nearly equal) to all that is being used at present in industrial agriculture and associated activities (ISIS/Mae-Wan Ho, 2008).

Reduction of factory-scale beef cattle production in the West would increase the mitigation potential by 1.6 percent (making the total 32.1 percent), and installation of biogas plants in crop livestock integrated farming systems would serve as net providers of energy to the farms.

David Pimentel and co-authors have shown that in the USA fossil fuel energy inputs for organic crop production were about 30 percent lower than that for conventionally produced corn (Pimentel *et al.*, 2005), which is indeed a considerable energy saving.

Productivity and other issues in ecosustainable organic agriculture

There is no valid reason to be afraid of the ultimate outcome of organic farming in terms of productivity loss in developing countries. Using a large data set, Catherine Badgley and coworkers (2007), working in the University of Michigan, have shown that at a stable state of soil, either under conventional or under organic or near-organic management (not during conversion from high intensive input to organic or near-organic systems), the yield ratios of organic versus conventionally grown food crops that included grains, starchy roots, sugar crops, legumes (pulses), oil yielding crops, vegetables and fruits (total number of studies had been 293) gave an average (average of all different types of plants) yield ratio value (organic versus conventional) of 0.914 (S.E. $\pm$ 0.02) for developed countries of the world, showing a minor yield reduction in those countries. In developing countries, on the other hand, the yield ratio value was 1.74 (S.E.$\pm$ 0.09) indicating considerable overall superiority of organic systems vis-a-vis conventional agriculture. Badgley *et al.* (2007) therefore suggested that organic agriculture could feed the world while doing away with the adverse impacts of conventional agriculture on environment and ecosystems.

A comparative analysis of the production data would show the superiority of intensively cultivated multicropping, especially of crop livestock integrated sustainable farming systems. Adoption of such systems in large industrial agricultural farms would involve standardization of suitable methodologies in due course. In countries at the low latitudes, they provide the most viable options and as reported by UNCTAD and other UN agencies they have already shown their effectiveness through doubling or near doubling of productivity (Schutter, 2011 Hoffman, 2011).

Biodiversity would be a key factor in ensuing high productivity. With an integrated eco-sustainable farming system in the Andaman and Nicobar Islands, Ravisankar and Pramanik (2007) could achieve a net income of Rs. 3 lakh in a farmer's 1 ha plot of land. They used 8 cropping schedules, one milch cow and two draft cattle, a set of layer birds, a small pond for pisciculture for the purpose.

Innovative methods like the system of Rice Intensification (SRI) which is essentially organic in principle can substantially increase grain yield besides saving 90% of the seed requirement and 50% of the irrigation water (Uphoff, 2003). Organic SRI and similar sustainable methods would be of great economic advantage to the small holder farmers.

Management of Nitrogen status of soil in organic agriculture : For optimal crop growth judicious management of nitrogen status in the soil in the absence of synthetic N-fertilizer application is a key issue in organic agriculture. The usual practices include returning crop residues to the soil, utilizing biological nitrogen fixation (BNF) to the maximum possible extent by selecting leguminous crops and wherever feasible using autotrophic N-fixers and managing effective schedules including mixed cropping; planned crop rotations would be of great advantage to the farmer.

Johanna Dobereiner, eminent Brazilian agricultural microbiologist brilliantly documented how Brazil, an important agriproduce exporting country became a nation with the lowest user of synthetic N-fertilizer (mean 10kg/ha). Brazil's major export product, soybeans are grown from varieties that require absolutely no nitrogen application, giving mean yield of 2 tons per hectare. Dobereiner(1997) calculated an overall economic benefit of US $3.2 billion from elimination of synthetic N-fertilizer and getting all the nitrogen of soybean through BNF. The association of diazotrophic bacteria such as *Beijerinkia indica* has shown the largest effect with sugarcane that can obtain up to 150 kg N/ha from BNF which has been the key to the success of Brazilian bioethanol production from sugarcane. Sugarcane grown without synthetic N-fertilizer application yielding 62 tons cane yield per hectare (average) is diverted to commercially viable ethanol production that now runs 4 million cars in Brazil replacing 260,000 litres of petrofuel per day. Incidentally, there is no subsidy on synthetic N-fertilizer in Brazil (which discourages its use, in our country the subsidy has been around 70 – 80% of the cost price).

Prospect of organic livestock production

Agriculture is a holistic proposition in which crop and livestock had been traditionally integrated till industrial agriculture delinked the association adversely affecting ecosustainability.

All animals, including carnivores (animals which eat other animals) directly or indirectly depend on plants for their food. As such, composition of animal-derived food products, such as milk, meat, egg, fish, etc. would be influenced by what the animals (livestock) eat, and as pointed out earlier, it is urgently necessary to be careful about livestock feed not only to safeguard their own health but also to ensure safe livestock products for human consumption.

Present day confined livestock production systems on large industrial scales for meat, milk, egg, etc. are churning out products that are far from ideal and contain pesticide residues, antibiotics, hormones and their metabolites that are definitely not safe for the children, pregnant and nursing mothers and the sick people. In an article in the popular TIME magazine (September 6, 2010), Jeffrey Kluger reports, "Beef raised in industrial conditions is dosed with antibiotics and growth boosting hormones leaving chemical residues in meat and milk." He cites a multicentre study in the USA that showed American girls as young as 7 are entering puberty at double the rate they were in the late 1990s, perhaps as a result of the obesity epidemic, but perhaps too as a result of hormones in their environment – including their food.

The conventional western industrial agriculture is based on intensive use of chemical fertilizers and synthetic chemical pesticides, farm machineries of different kinds involving high dependence on fossil fuels and minimum use of human labour and therefore anti-marginal and small farmers in principle and practice. In livestock raising – dairy farming, poultry keeping, meat production, etc. the same principle of intensive use of inputs to maximize productivity is followed. High population density of animals and birds, stall or confined feeding systems, heavy dependence on grain feeding rather than grazing or free range movements, use of excessive antibiotics as precautionary measures against spread of diseases, steroids and growth hormones for high production in a short time span are essential features of these milk or meat factory-like production systems with strong possibility of adverse health effects. Inspite of higher per capita output these mass production systems are environmentally degradative, antinature and unsound from the viewpoint of health and hygiene with products that are low in nutritive values. The average decline of over 200% in the levels of nutrient elements in fruits and vegetables in the USA and UK over the last few decades is indeed a matter of serious concern for human health, and also of livestocks dependent on vegetative feed, as a consequence of the shift from traditional biodiversity-rich agriculture to industrial agriculture with a fewer kinds of crops (Worthington, 1999; 2001). The danger to biodiversity by genetically modified crops was categorically demonstrated by Quist and Chapela (2001) over a decade back showing transgenic DNA introgression into traditional maize land races in Oaxaco, Mexico, a centre of origin of maize. There was a great deal of controversy over the issue created by the proponents of GM technology but recent reconfirmations have fully corroborated alien gene introgression. Retired US scientist Don M. Huber, a reputed researcher on glyphosate (trade name Roundup), world's top herbicide and a must for widely grown genetically modified (GM) Roundup Ready maize and soybean crops, has recently come out with a revelation in a letter to US Secretary of Agriculture, Tom Vilsack that glyphosate is perhaps the most damaging chemical used in agriculture and is responsible for numerous adverse effects that include among others an alarming rise in sterility of farm animals, spontaneous abortions and still births and perhaps a host of human diseases caused by direct and indirect consumption of food linked with glyphosate and Roundup Ready GM crops. Aris and Leblanc (2011) have convincingly demonstrated the crossing of placental barrier by GM associated toxins in the first ever study with pregnant women in Quebec in Canada. All these evidences along with the meta-analysis of data on GMO feeding experiments (Seralini *et al.*, 2011) would suggest that industrial agriculture fortified with GMO technology would be all out to corporatize agriculture and ruin farmer controlled ecosustainable agriculture that only can assure long term safe food and nutritional security along with food sovereignty of the developing countries; these countries are already in the grip of the adverse effects of global climate change initiated and aggravated by the rich highly industrialized countries in the West.

Indian Small-holder Farmers : Strategies to meet the Challenges

Directly and indirectly over 60 percent of the Indian population are dependent on agriculture and allied activities. The small-holder farmers are socioeconomically extremely hard pressed, climate change will inevitably aggravate their food and livelihood security.

The report of the Suresh Tendulkar Committee, submitted to the Planning Commission in December 2009, reveals that at the national level 37 percent of Indians are below the poverty line (BPL) (about 10 percent more than the previous estimate). If only rural areas are considered, the figure goes up to 42 percent implying that nearly half of rural India is starving. It is a pity that most of them are the people who produce food to feed the nation.

In an article on world food crisis in 2008, Sundaram (2010) cites from the World Food Programme country page for India, “nearly 50% of world’s hungry live in India, a low-income, food-deficit country”. While economic growth has probably increased incomes and food consumption for many, many more seem to be worse off. In this connection, it is worthwhile to recall the 2007 Arjun Sengupta report of the National Commission for Enterprises in the Unorganised Sector, that shows the total number of poor and vulnerable people increasing from 732 million in 1993 – 94 to 836 million in 2004 – 05, while 77% of India’s working population lives on a little over half a US dollar a day. Small holder farmers and farm labourers who constitute the majority of the persons in the unorganised sector have been the worst sufferers of the crisis.

Major reasons behind the present setback of farming in India

Of the various reasons of the distress, the important ones may be cited as follows:

i) Agricultural growth in the country is falling behind population growth, excessive fragmentation of holdings, soil degradation due to lack of soil management and wrong agricultural policies and practices; high input costs – as such, farming is becoming uneconomic and nonremunerative.

ii) Loss of biodiversity, crop biodiversity in particular, has been a major fall-out of the so-called green revolution technology (GRT) in view of the fact that thousands of varieties of different crops (especially cereals, pulses, oilseeds and vegetables) have been irretrievably lost because farmers who have been maintaining them (and also adding to their numbers) for specific agro-ecological niches and special purposes shifted over to a handful of GRT varieties. Genetically modified crops have further jeopardized crop biodiversity. Faunal diversity (particularly the population of beneficial and farmer-friendly insects, amphibians and birds) has been greatly reduced by the pesticide menace.

iii) Globalization of agricultural trade is encouraging cash crops over staple foods; export orientation in the face of unequal competition from highly subsidized imports is also adversely affecting farmers.

iv) Climate change is negatively impacting agricultural production specifically in low latitude countries like India. Of these, most are beyond the immediate control of the average small-holder farmer except short term changes (and in due course medium and long term adaptive changes) in farming practices.

v) Increasing corporatization of agriculture and food systems would pose a very serious threat to the livelihood and survival of our small-holder farmers.

The sole focus on production increase at any cost through conventional (industrial) chemical-intensive agriculture and its all pervasive formula of "fertilizer (NPK)-irrigation water-pesticides", with initial short term success, has in 3-4 decades ruined the natural fertility of the soil, greatly diminished soil organic matter, the abode of soil microbes, extensively depleted the aquifers, almost irreversibly polluted air and water and incurring huge external costs with no attempt to minimize the cost of production. The tolerance of the insect pests to pesticides has reached a point where even the expensive third and fourth generation toxic pesticides are failing to control them. Increased applications of NPK fertilizers are becoming counterproductive, the deficiency of secondary nutrients and micronutrients is widespread. Further cost of fertilizers is increasing in the world market and as the country now imports over 40 percent of nitrogen, 97 percent of phosphorus and 100 percent of potash at international price and makes that available at around 25-35 percent of actual costs, the situation is destined to turn serious in the near future. According to Roberts and Stewart (2002) economically recoverable phosphorus in the world would be available may be for another three decades only (global potassium resource, however, may not deplete before another 100 years or so). The depleting fossil fuel reserves will certainly affect mechanized agriculture and will also limit their use in production of fertilizers, pesticides etc. Recycling of crop residues and all organic wastes in a closed agricultural system (earth itself with limited resources is also a closed system but for the almost unlimited and inexhaustible supply of solar energy) would perhaps be the only viable option left to millions and millions of small-holder farmers not only in India but also in all developing countries (Altieri, 2008) more so in the perspective of climate change intensifying its negative impacts on most human activities including agriculture.

In natural resource management based agricultural systems the dependency on synthetic fertilizers, pesticides, fossil fuels, etc. should ideally be nil but from a practical viewpoint, as low as possible to tide over initial set-backs in the absence of adequate experience and training in genuine ecologically sustainable farming practices. High yielding varieties (HYVs) are in fact high input requiring varieties and in the changed situation they must be avoided as far as possible. The presently available expensive genetically modified (GM) seeds which are also tailor-made for specific inputs, besides their still unknown short and long term effects on health of the ecosystem including that of humans and livestock and allied plants of the same family must not be included in the cropping schedule of the farmers whose seed requirements should be basically made from locally adapted crop cultivars.

Hybrids are also high input requiring seeds and cannot be saved for next sowing. Incidentally all GM cotton cultivars commercialized in India are hybrids as also all other GM crops in the pipeline. So the farmer would be unable to save the seed for next sowing. Under no circumstances, the farmers as individuals or communitywise should be deprived from their traditional right to save the seeds of crops raised by them. As such, setting up seed villages with emphasis on locally adapted varieties also those in the public domain, and provision of adequate support systems and training must be encouraged throughout the country.

Farming Systems Options for Small-holder Farmers

As against the top-down approach in conventional industrial agriculture, all natural resource management based ecosustainable agricultural systems should be essentially bottom-up in nature. All decisions in the individual farms and at the community level must be taken after a threadbare discussion with experienced farmers, *panchayat* (village cluster level) and block level functionaries.

For the small-holder farmers at the village level several options are given hereunder, the choosing of appropriate ones depending on the situation would enable them to considerably meet many of the impending challenges of climate change.

i) Digging rainwater-harvesting structures such as ponds, dug wells of different sizes, shallow rectangular water harvesting structures for lands with gentle slopes in drought prone areas, contour bunds across the slope to arrest the runoff and consequent erosion of the soil. The fertile topsoil along with invaluable plant nutrients would otherwise be lost irretrievably to the sea via creeks, canals and rivers.

ii) Land shaping to raise low lands to accommodate a pond and raise a part of the land (surrounding the pond along with the bunds around the plot) to enable growing of fruits and vegetables in the uplands, paddy with fish in low land, paddy (HYV) in the medium land; the pond serving as rainwater harvesting structure would supply irrigation water in the lean period (*rabi* season) besides raising fish and rearing ducks for nutritional security and food security. Rainwater harvesting and crop-livestock integrated farming system (IFS) would assure year round employment generation and a 2-3 fold net rise in income (Swami Sadananda, 2005; Ghosh, 2006; Ravisankar and Pramanik, 2007). Cattle keeping for draft, milk and cowdung, the latter in many instances has enabled installation of small biogas plants (Ramarao *et al*., 2005, Ramasamy *et al*., 2007) to supply cooking fuel and slurry as valuable manure (also used for vermicompost preparation and as fish feed).

iii) Wherever possible adoption of System of Rice Intensification (SRI) for paddy cultivation is suggested; it would save nearly half of the water used in conventional cultivation, seed rate will be less than one fifth; with organic manure only, an increase in yield to the extent of one ton per hectare may be expected. SRI in *rabi* season on 20 percent of paddy area would enable a significant diversion of land to pulses, oilseeds and wheat that are in short supply. The acreage should go up by 10 percent annually. Necessary motivation of farmers along with arrangements for training will go a long way in popularizing SRI. As in SRI much less water is used, production of the greenhouse gas methane would be less. SRI would impart more tolerance to climatic stresses such as dry spells and erratic rainfalls. Data from northern India in the drought year of 2009, showed that conventional paddy yield declined by 31 percent while with SRI yield declined by 13 percent only (Adhikari *et al.*, 2010, also see Uphoff, 2003).

iv) The Non-Pesticidal Management (NPM) of insect pests, presently covered under Community Managed Sustainable Agriculture (CMSA) has by 2009 spread to 1.39 million acres (estimated at 2.8 million acres i.e. 1.12 million hectares in 2010) in Andhra Pradesh involving 318,000 farmers of 3,171 villages in the state (Vijaykumar *et al*., 2009). NPM has been similar to Integrated Pest Management (IPM) but one step ahead in that it altogether discarded chemical pesticides (the last resort for pest control in IPM). Summer ploughing, bonfires, and pheromone traps, use of trap crops, bird perches, light traps, spraying diluted fermented cow dung–cow urine along with range of botanical preparations would substantially reduce pest attack, significantly lowering the cost of cultivation. Although initially CMSA has been continuing the use of chemical fertilizers, those are being gradually phased out with emphasis on soil fertility management through application of tank silt, composts and vermicomposts (augmented by biomass plantation on farm bunds, azolla culture in rice) and inoculation with nitrogen fixing bacteria, etc. With total shift to organic farming within several years, the emphasis will be on intercropping and biodiversity-based multi-cropping. The Govt. of Kerala has already adopted a state policy of a total shift to organic agriculture within 5 to 10 years to save the farmers from the current multidimensional agrarian distress and to protect the environment from further degradation and bring back Kerala's pristine ecosystems (Vijayan, 2010).

It is worthwhile to note in this connection that within a short period the certified area under organic agriculture in India has gone up to over one million hectares, with Madhya Pradesh heading the list of the practicing states. Another feature is the sharp reversal of trend of consumption, the earlier export oriented organic agriculture has given way to domestic consumption of nearly 96 percent of the total produce of 976,000 tons (valued at 2.63 billion US dollars) in 2007-2008; the 3.8 percent export of organic produce gave a foreign exchange earnings of 100 million US dollars (Export-Import Bank of India, 2010). The demand of metropolitan cities is estimated to be around Rs.1.4 billion annually (Menon, 2007). Greater adoption of organic farming systems would be a key factor in mitigating GHG emission (Mae- Wan Ho, 2008) besides enhanced nutritive values and health benefits of organic food (Lu *et al*., 2006; Mitchell *et al*., 2007).

v) The small-holder farmer is sensible enough to give enough priority to food and nutritional security of the family but very often unable to ensure that because of acute poverty. A community based approach through which the farmers would first meet the basic needs of the community by cultivating (through mutual arrangements) a wide range of crops for nutritional security, and after meeting local needs, sell the rest to the nearby semiurban or urban markets. Transport cost is steadily rising and along with that the "food miles" related GHG emission; as such, localized food production and consumption (collectively known as localized food system) are widely advocated by environmentalists all over the world (ISIS/Mae Wan Ho, 2008). Unfortunately the corporate controlled food and agricultural sectors, as in the developed countries in the North, follow totally opposite policies and strategies on the issue and to them neither food and nutritional security nor environment would mean the same thing as they do to the poverty stricken small and marginal farmers fighting for mere subsistence.

Analysis of Major Observations, Discussion and Conclusions

Late 21st century at about 2085 or so, would be the predicted time of "benchmark 2 x CO_2 warming" when CO_2 concentration in the atmosphere would be double of its approximate preindustrial (around 1750 CE) level of 280 parts per million (ppm). With the large impact of around 560 ppm CO_2-equivalent GHGs, global temperature is predicted to rise by around 3ºC with large regional deviations. Two apparently opposite effects on agriculture; firstly, GHG induced global warming and climate change adversely affecting agriculture in the developing countries in particular, and secondly, a high level of CO_2 boosting plant growth via increased carbon assimilation in photosynthesis, a phenomenon known as carbon fertilization (CF), which in theory could partly compensate the negative effects of global warming, are involved in the assessment of agricultural impacts.

The salient observations in the present production scenario, the probable effects in the future and strategies involved to meet the challenge of the global warming are presented and discussed hereunder.

1) Agricultural crops, specially the annuals are the major harvesters of solar energy for food, feed and also raw materials for many industries and they are the primary producers (along with all chlorophyllous plants in the wild) as they only are capable of carbon assimilation through photosynthesis using solar energy; practically all other organisms of the biosphere are dependent on plants for their survival and existence. It needs to be remembered that the key mover of the present day civilization the fossil fuels (coal, shale, natural gas, petrofuels) are all products of ancient photosynthesis. Because of the dependence of crop plants on specific optimum temperature regimes, growth and development and ultimate yield potential of agricultural crops, would be adversely affected by a rise in temperature beyond that to which the different kinds of crops are acclimatized.

2) The atmospheric temperature is the major determinant of climate dynamics in general, via general circulation patterns of air currents in the atmosphere and water currents in the seas and oceans, the extent of precipitation, both in respect of quantity and pattern, would be influenced greatly by temperature rise.

   Temperature rise would, however, initially benefit countries in the higher latitudes through extension of growing period and warmer days.

3) The most important causative factor of global warming, the greenhouse gas CO_2 has the highest overall global warming capacity. However, unlike other GHGs such as methane, nitrous oxide, F-gases etc., carbon dioxide has a dual role and contrary to its adverse effect on agriculture due to global warming, the rising CO_2 level would promote photosynthetic carbon assimilation as a basic input of the process known as carbon fertilization (CF) as mentioned above. Depending on several factors particularly the CO_2 assimilation pattern (C3 or C4), the contribution of CF at high CO_2 levels could be as high as 15-20% under favourable edaphoclimatic conditions compensating to a significant extent its negative role through unfavourable rise of ambient temperature. However, C3 plants in which the first stable compound in photosynthetic carbon assimilation is phosphoglycerate with three carbon atoms in the molecule (such as rice, wheat and other fine grains, potatoes, legumes and most trees) would benefit more than C4 plants

with the first photosynthetic stable compound, oxaloacetate, a four-carbon compound (in crops such as maize, sugarcane, sorghum and millets).

4) A total of 51 countries representing diverse agriculture of various geographic locations and agroclimatologic conditions show commonalities as well as differences in respect of choice and proper selection of crops and livestock. The top commodity (biggest revenue earner) in 2010 in over half the countries of the world is a livestock product such as cow milk, cattle meat or other meats, with the rest nearly half of the countries showing a grain or another staple crop with rice as the most dominant one in the South and Southeast Asia (66% of agricultural revenue of Bangladesh is from rice alone). Unconventional top commodities include palm oil (53.2% of total agri-output) in Malaysia, soybean (36.6%) in Argentina, grapes (22% in Chile,17% in Italy), sugarcane (20.3%) in Brazil, tomatoes (20%) in Egypt and Iraq, plantains (14.8%)in Cameroon etc.

5) Overall as a provider of food the role of cattle is overwhelming and almost universal, globally total agricultural production in 2010 is valued at $1470 billion and out of that the contribution of two cattle products milk and meat has been 23.6%, a whopping $347 billion (cow milk $179 billion, cattle meat $168 billion). The share of cattle products in New Zealand is over 71% of the total agricultural commodities.

   Incidentally, beside usual cattle products, that also include a large share of hide and skin for the leather industry, cattle (bullock/ buffalo) physical power is a major source of traction needed for ploughing, threshing and transport in many developing countries in South and Southeast Asia and elsewhere.

6) Total agricultural output in 2010 has been highest in China with $343 billion distantly followed by USA ($195 billion), India ($165 billion), Brazil ($115 billion), Indonesia ($51 billion). The others between 50 billion to 20 billion annual output include Argentina ($39 billion), Russian Fed.($35 billion), France ($34 billion), Pakistan ($32 billion), Germany ($29 billion), Mexico ($28 billion), Spain ($27 billion), Thailand ($26 billion), Vietnam ($26 billion), Italy and Turkey ($25 billion each), Canada ($24 billion), Australia ($21 billion) and Bangladesh ($20 billion) and so on. Agricultural GDP is in the declining mode in developing countries and in most OECD countries the same varies from 1-3 percent.

7) Per capita output is highest in Uruguay ($2427) because of very high land availability per person (4.32 ha/capita). Although Australia, the country with maximum per capita farm land availability (21 ha/person) shows per capita output of $989, the output per ha is too low in Australia ($47/ha) to compensate , and as such, per capita output falls behind Uruguay.

   Argentina because of low population density gives a per capita output of $951. However, inspite of a high output/ha of $2333, Bangladesh with per capita land availability of 0.05 ha shows a per capita output of only $123, very close to India with $135 output per person. Despite its overall supremacy in agricultural production, the per capita output of China is moderate ($254/person) because of its huge population of over 1.35 billion. Maintaining a per ha output of $974 over a huge area is undoubtedly highly commendable in view of the fact the same is nearly double of the output per ha of USA ($494), the citadel of present day industrial agriculture.

8) Output per ha obtained by dividing total agricultural production by farm area of a country is certainly an effective measure of efficiency of the farming systems and practices followed in a country. Among the 51 countries selected, the highest output per hectare in 2010 is that of the Netherlands ($6110/ha) and is attributable primarily to the livestock sector (LS),which accounts for over 75% of its agricultural revenue), the second position goes to Egypt ($4057/ha), crop sector (CS) dominated and 100% irrigated, only 3.9% of the land area arable through irrigation with Nile water, followed by Japan ($3379/ha), Belgium ($3287/ha),Vietnam ($2734), Bangladesh ($2333/ha), Malaysia ($1795/ha), Philippines ($1699/ha), Germany ($1593/ha) and Switzerland ($1574); Australia ($47/ha) and the Russian Fed. ($47/ha) are lowest in respect of output per ha. Others with low productivity include Bolivia ($71/ha), Zambia ($96/ha), Madagascar ($144/ha), Mexico ($191/ha), South Africa ($209/ha), Iraq ($270/ha). South and Southeast Asian countries on an average show outputs around $1150/ha (ranging from $938 in India to $1325 in Thailand and $1461 in Myanmar). The four large agricultural economies namely China ($974 /ha), USA ($494 /ha), India ($938/ha) and Brazil ($374 /ha) reveal that output per ha in China and India is nearly double that of USA but income per hectare is still lower in the latter because of higher cost of production. This fact would further show that the highly industrialized agriculture model is generally far behind that of middle and many low income developing countries so far as real income from an unit area of arable land is concerned. Without huge state subsidy farmers in high income countries will certainly opt out of farming.

9) The mean income per hectare (average of 5 years from 2006-2010) has been $197/ha in the USA, against $600/ha of India and $569 of China and $1431 /ha of Bangladesh (over 7 times that of USA). Egypt is an example of efficient use of water availability for irrigation with an income of $3210/ha (16 times more income per ha than the USA). Though cost of cultivation in the Netherlands with mean output of $5809/ha is high, the average income/ha is also quite high ($2614/ha, 13 times more than USA). It needs to be pointed out that the income /ha is mostly from the livestock sector as would be true for many OECD countries that import feed grains from other countries while that in the developing countries come almost wholly from domestic production.

How the farmers in the high-income industrialized countries like the USA or those in the Europe could be satisfied with such low farm incomes, even though their per capita farm area in general (excepting countries like Japan) is much larger than in the average developing countries, is indeed a pertinent question. The answer to the same is the huge cash subsidy given by the governments to the farmers in the OECD countries amounting to a total of over 1 billion dollars per day (it was $374 in 2006) that would result in cheap abundant agricultural products. This is a tradition continued over a long period. OECD annual subsidies a decade back in 2001 amounted to 311 billion dollars; it is really difficult to visualize the annual dairy subsidy in Japan as $2700/cow or US domestic subsidy for cotton equal to 10 million $per day (Birdsall and Clemens, 2003). All this would result in state subsidized cheap abundant produce often priced well below the actual cost of production making the producer farmers gainers as they make higher profits through subsidies. No wonder data from FAOSTAT data base quoted elsewhere in the text showing either no increase in producers' price for livestock products and only minor increases for some of the crop sector products over the 10 year period, 2001-2010 (that includes the year of global financial crisis, 2008 when prices of most commodities went up sharply). Though consumers pay less for cheap food they pay more in taxes to cover the subsidies that are heavily biased towards large producers. According to the European Commission estimates, excluding Greece, half of all subsidies would go to just 5% of the farmers (Cline, 2002). Further, net food importing countries benefit from cheaper world prices. But in the long run, low prices dampen incentives to invest in agriculture leading to stagnation of a sector, on which many poor people of the developing countries in particular, depend for livelihood. Consequently, farmer producers of rich countries would remain as the sole true beneficiaries of subsidies with a multiple of losers across the globe (Cline, 2002).

In a critical analysis of the 2008 world food crisis, Sundaram (2010 has very categorically called for restoration of public support for food production. International public support has fallen off since the 1980s with the so-called reforms initiated by the World Bank, IMF and WTO with disastrous effects on the developing countries. There is no hiding of the basic fact that corporatization of agriculture has been the main issue behind the withdrawal of public support as manifested in the rapidly increasing influence of the agribusiness corporate interests on public policy, trade regulations and access to technology that may ruin peasant agriculture in the developing countries.

10) The relative share of the crop and livestock sectors in agriculture appears to be closely related to the economic status of different countries. Generally in developed countries the total contribution of livestock sector as well as the percentage share of the livestock sector are significantly higher than in the developing countries. In 2010, the livestock sector in the New Zealand valuewise has been as high as 91.3% of total agricultural production (i.e. crop sector 8.7%), it accounted for 90.7% in Norway, 80.7% in Switzerland, 75.3% in the Netherlands, 73.5% in UK and so on. For big agricultural economics like China, USA, India and Brazil the livestock sector contribution were 54.5, 53.1, 32.5 and 44.1 percent respectively. While rice based agriculture in South Asia the crop sector account for 89.7% in Cambodia (LS 10.3%), 88.9% in Indonesia, 88.4% in Sri Lanka, 86.5% in Bangladesh, 77.7% in Malaysia, 74.5% in Vietnam. For India the crop sector contribution has been 67.5%, while the same for Pakistan was 41.5% (LS 58.5%). The share of CS in the World in 2010 has been 49.1% against 50.9% of the LS.

11) Global production scenario in the first decade of the 21st century shows that average value of annual production over the 10-year period was $1337 million, with per ha output of $333 of which $171 was contributed by livestock sector. Total (CS+ LS) income was $116 per capita. Global crop sector includes rice (mean annual production 634 mmt), wheat (622 mmt), soybean (213 mmt), maize (729 mmt), potatoes (322 mmt), vegetables (329 mmt), tomatoes (131 mmt), grapes (60 mmt), apples (64 mmt), bananas (82 mmt), mangoes (39 mmt), sugarcane (1477 mmt), cotton lint (22.5 mmt), cassava (209 mmt).

The livestock products (average annual production in million metric tonnes) were cow milk (550 mmt), buffalo milk (80 mmt), hen eggs (58 mmt), cattle meat (60 mmt), chicken meat (72 mmt), pig meat (100 mmt) and sheep meat (8.2 mmt). Globally average meat availability per person (composite, all meats taken together) has been 37 kg per year (on conversion to mutton equivalence, it would be 25 kg, but 48 kg as chicken equivalent (equivalence based on price in US dollars – vide FAOSTAT database). Over the full decade (first decade) of the 21st century the annual increases in the two major food grains, rice and wheat have been 1.52% and 1.30% respectively; in case of potatoes it is 1.26%, for vegetables 0.58% only and for grapes the annual increase is 1.16%. Satisfactory increases have been recorded with bananas (4.78%), soybean (4.52%), maize (3.68%), tomatoes (3.52%) and sugarcane (3.37%). Comparison of half decades within the decade namely 2001-05 and 2006-10 reveals a decline in the rate of increase in most cases; specifically a negative trend with cotton lint (-0.8%) and vegetables (-0.4%) was noted in the second half (2006-2010).

The decline in crop sector, grains in particular was partly reflected in the livestock sector of cow milk and cattle milk production but not on chicken meat, egg and pig meat production.

12) Indian agricultural production scenario in the first decade of the 21st century shows that the production of the major crop, rice has virtually reached a plateau, over the full decade the average annual rate of change being -0.82%. The two major grains rice and wheat showed an average increase of 1.13% in the first half of the decade (2001-05) and 0.60% in the second half of the decade (2006-2010), which surely is an ominous sign of decline of the two all-important staple grains of the country.

The data for a good many of the crops are characterized by considerable ups and downs attributable mainly to fluctuations in monsoon rainfall pattern (and extent in terms of mm/day) over the years. To the farmers in different parts of the country the increasing erratic behaviour of the monsoon is certainly becoming an issue of great concern.

India is presently the biggest milk producer of the world with 130 mmt annual production in 2010 as cow milk equivalent value (CME value obtained by multiplying buffalo milk by 1.314 and adding the same to cow milk). However, per capita availability of 107 kg per year is far below that of high income countries because of large population of the country. The decadal increase in the production of milk averaged 4% per year; the same for egg production was 5% per year. Meat production (composite) in 2010 was 4.85 mmt with per capita availability of only 4 kg/per year for a predominantly vegetarian population of the country (compared to 128 kg/capita/yr in the USA). It needs to be pointed out that feed grain based livestock production as in most developed countries would be difficult in India because of overall shortage of grains. The rise in chicken meat consumption in the recent years is due to its affordable price attributable to much less feed energy requirement than most other meats.

13) Global climate changes especially temperature rise in the late 21st century have been tentatively quantified and projected in a number of climate models

technically known as general circulation models (GCMs). Broadly, increase in temperature would be around 3°- 4°C. As such, temperate countries with average temperature of 10°C will certainly benefit from such temperature rise but countries in the low latitudes with average temperature above 20°C, there is a strong likelihood of adverse agricultural impacts. In majority of the developing countries, the existing temperatures are above the optimum levels therefore further temperature rise due to global warming would reduce agricultural productivity.

Precipitation that determines water availability to crops would be characterized by ups and downs. Tropical areas would have increased mean precipitation; most of the subtropical areas would show decreased mean precipitation while in the high latitudes the mean precipitation would increase.

Precipitation projections from average base values (*bv* in mm/day) between 1961-1990 vis-à-vis that during 2070-2099 for some selected countries would be as follows: Bangladesh +0.62mm/day (from a base value, *bv*) of 6.42 mm/day) , India +0.47(*bv* 2.8), Myanmar +0.44(*bv* 5.47), China +0.31(*bv* 2.24), Thailand +0.31(*bv* 3.8), Indonesia +0.28(*bv* 7.74), UK +0.24(*bv* 3.313).The decrease in precipitation for some countries would be: for Spain -0.33 mm/day (base value 1.76mm/day), Mexico -0.25(*bv* 2.09), Madagascar -0.21(*bv* 4.12), France -0.20(*bv* 2.33), Italy -0.15 (*bv* 2.48)and no change in Egypt. Precipitation is projected to decline in Southern United States, Eastern half of Brazil, Western half of Argentina, most of Australia and the Mediterranean region. An increase of 0.5% is projected for much of sub-Saharan Africa, China and Russia, Northern USA and Canada.

14) The dispersion of Ricardian Agricultural Impact model across six climate models shows large declines in land rental equivalence attributable to global warming for many countries such as Colombia, Venezuela, Brazil, Zambia, Madagascar, Mexico etc. Many cold and temperate countries such as Russia's Black Sea region, US Lakes and North East region, Germany, Central China, UK are projected to gain from global warming.

Employing the crop or agronomic model, the decline in yield would be still higher with Pakistan showing -25.5%, followed by Mexico (-23.8%), Egypt (-18.8%), Brazil (-16.3%), India (-14.3%) and so on; New Zealand is projected to show an increase of 18.8%.

William Cline's summary on global warming impacts on agriculture based on his concept of preferred estimates categorically brings out the fact that the industrial countries (mostly OECD countries) stands to gain nearly 8% if carbon fertilization (CF) due to enhanced CO_2 in the air boosts up carbon assimilation in photosynthesis as projected in Ricardian and agronomic crop models, otherwise they would also suffer a loss of productivity in the long run (Cline, 2007).

15) Agriculture situations in the late 21st century at around "benchmark 2 x CO_2 warming" that is approx. 560 ppm CO_2-equivalent concentration of GHGs has been worked out in several agricultural impact models. William Cline (2007) took into consideration the average annual increase (%) in yields per hectare of 4 major grains that are key to food (and feed) security. Firstly, the weighted average increase in

yield per hectare of the four crops were calculated and then based on their wheat equivalent weights the average annual percent increases in yield over the periods 1961-83 and 1984-2005 were estimated. The mean values for the two periods have been 2.81% between 1961-83 and 1.57% for the period 1984-2005. With the later value, 1.57% in 2005, on the supply side the expansion factor (l_q) for yield in 2085 (i.e. after 80 years) was calculated as l_q = $(1.0157)^{80}$ = 3. 84; implying thereby a grain supplies 3.84 times that in 2005 with the aforesaid growth rate. However a 30% diversion of land because of other purposes, especially bioethanol production, supply would be reduced to 3.48 x 0.7 = 2.43 (=l). On the demand side, population expansion (upto 2085) factor (l_N) would be 1.628 and income elasticity for food (l_Y) would be equal to 1.629, these two on multiplication would be equal to 2.65 (= $l^{D,}$ the demand expansion factor); as such, demand would exceed supply by approximately 9%. If the progressive decline in yield per hectare is taken into consideration and the starting annual rate of increase up to 2010 is calculated, the same would be equal to 1.288%; as such, l_q would be equal to $(1.01288)^{75}$ = 2.611, other things such as land diversion remaining the same, the supply expansion factor l^S would be equal to 1.828. Population expansion factor (l_N) from 2010 to 2085 would be equal to 1.54 which multiplied by income elasticity factor of 1.580 (over 75 years) would be equal to a revised demand factor (l^D) equal to 2.432. The resulting mismatch would result in a 33% overall deficit in productivity.

16) Strategies to meet the inevitable mismatch between demand and supply of agricultural products in the world in the late 21st century must be carefully worked out. In the developing countries in the low latitudes, the deficit in supply will be observed much earlier. The big question is how to meet the challenge and ensure food and nutritional security to people of low income countries with low purchasing power. As has been shown earlier the demand for agricultural products is determined by the number of people in the country and income elasticity factor (within limits demand will increase with rising income) while supply is determined by productivity per unit area and diversion of land for purposes other than food, feed etc; for example bioethanol production from maize, sugarcane etc. for transport fuels. To reduce demand it would be necessary to reduce population growth. The rate of population growth has almost stabilized in the developed countries; in fact in a number of countries it is already negative. In developing countries policy planners must work with socioreligious and political leaders to ensure population stabilization as early as possible. The very sensitive issue of birth control would demand persistent persuasion rather than any kind of compulsion. Nevertheless, there is no viable alternative to strict family planning.

17) Another important issue is the growing demand for livestock products (milk, meat, egg, fish oriented diet) which are nutritionally rich. Globally marine and aquaculture products account for around 3% of food consumed but the supply is diminishing; over-fishing has already depleted major marine fisheries and pressure on different animal meats is steadily rising along with increasing demands for milk products and eggs. The

generation of animal products greatly depends on feed grains and forage in many cases. Animal products require much more energy for production than plant products in general. For a kilogram of cattle meat 13 kg of feed grains and 30 kg of forage would be necessary in confined or stall feeding. The same for mutton would be 21 kg of grain and 30 kg forage, for pig meat the grain requirement to produce a kg of meat is 5.9 kg, but chicken is less energy intensive and only 2.3 kg of grains would be necessary for 1 kg chicken meat.

For a kg of dairy milk, 0.7 kg of grains and one kg forage would be sufficient because of high water content of milk. A kg of hen eggs (approx. 13 numbers of eggs, each 75 grams 'A' size) would require 11 kg of feed grains. As such, if the total cattlemeat produced in the world in 2010 (= 62.1 mmt) were obtained through confined feeding the total grain requirement for beef production alone would be 807 mmt, the corresponding requirements would be 644 mmt for pigmeat , 196 mmt for chickenmeat, 180 mmt for mutton,700 mmt for egg, 504 mmt for dairy milk-giving a total of 3032 mmt of feed grains that far exceeds the total grain production in the world (2429 mmt in 2010). Fortunately, intensive industrial meat production with confined feeding is practiced mostly in rich industrialized countries; otherwise an acute shortage of food grains would have resulted in malnutrition and increased number of hungry people in the developing countries.

For nutritional security, emphasis need to be shifted to good quality vegetable proteins such as the beans and a host of pulses as well as fish and egg raised in integrated sustainable farming systems; amongst the meats, the less energy intensive (as such less expensive) meat, like that of chicken may be consumed at intervals. There are numerous examples of crop-livestock integrated systems in India in which poverty reduction and nutritional security have been achieved by small and marginal farmers employing water harvesting and conservation technologies and integrated farming systems approach.

18) There are serious concerns over the sustainability of marine fisheries. Hundreds of millions of people eat fish as an important source of protein. On an average consumption of fish per person in North America is 24 kg a year, the same is 18.5 in Asia and 9.2 in Latin America and Caribbean. But fishing that exceeds the natural rate of regeneration and suffers considerably from discharge of pollutants, dredging; dumping, coastal tourism etc. undermines the conditions required for healthy marine ecosystems threatening their sustainability (Human Development report, 2011).

Although the annual estimated fish catch that is ecologically sustainable ranges between 80-100 million tons, currently 145 million is the quantum of annual catch that far exceeds the capacity of marine fisheries. In 2008 the FAO estimated that 53% of known fish stocks are fully exploited, 28% were over exploited, 3% were depleted and only 15% were moderately exploited. Although total output has not fallen, yields for some species, especially larger fish, have declined considerably since the 1980s.

It is seen that some 10% of the fishing activity by developed country fishers account for 90% of the total fish catch through advanced fishing vessels and associated sophisticated technologies for fishing in deep waters. Average annual production (effective catch) per fish farmer is 172 tonnes in Norway, 72 in Chile, 6 in China and 2 in India. Although 85% of the people in fish industry work in Asia, annual production in the region is 2.4 tonnes per ocean fisher compared to 23.9 tonnes in developed regions such as Europe. However, large commercial fishing companies not only catch more fish but cause lot of damage using high bycatch (unintended catch) method and bottom trawling catch rates are still rising despite initiatives by governments, partly because of high demand for export to developed countries where consumption per person is still on the rise.

19) The life supporting services provided by healthy and resilient ecosystems depend on the biodiversity they contain. However, globally rapid loss of biodiversity is taking place with serious declines noticed in the last decade in fresh water wetlands, sea ice habitats, salt marshes and coral reefs. Multiple indications of continuing decline in biodiversity in all three of its main components- genes, species, and ecosystems have been pointed out in the "Convention on Biological Diversity's Global Diversity Outlook 3". It records that natural habitats in most parts of the world are shrinking and nearly a quarter of plant species are estimated to be threatened with extinction (Human Development Report, 2011).

Environmental scientists are of the opinion that a mass extinction of species may take place with half of the earth's estimated 10 million species disappearing in the 21st century. The biggest cause of this loss is attributed to conversion of natural (wild or forest) areas to agriculture and urban development. Other causes include the introduction of invasive alien species, over exploitation of natural resources, pollution, and increasingly, the effects of climatic change.

It is projected that some 10-30% of mammal, bird and amphibian species are threatened with extinction, more so in poorer countries which would justify the location of biodiversity hotspots (areas with the richest and most threatened resources of animals and plant life) in tropical areas.

The impact biodiversity loss is very severe on poor communities in developing countries who rely heavily on natural resources and wild foods that are their important source of minerals and vitamins especially of many African communities. Use of wild foods can also reduce disease transmission in complex tropical ecosystems.

20) Tackling the root cause of climate change, GHG emission into the atmosphere is essential to meet the challenge but requires a global approach. Unfortunately, the latest international mitigational efforts on that have been sabotaged by the USA, the principal perpetuator of the crisis. Unilateral voluntary efforts by several countries have yielded some positive results in emission cuts but much more is needed to safeguard global environment. In the meantime autonomous adaptation options such as changing varieties and species to adjust better to changed climatic conditions, changing time of irrigation, altered nutrient management, changing time and location of agricultural activities and diversification of agriculture, promoting water conservation technologies and using agro-biodiversity need to be critically explored and adopted for increased resilience of agricultural systems.

Planned adaptation includes policy decisions on livelihood security, infrastructural support for new knowledge and technology and management practices tailored to anticipated changes in climate.

Global policies and politics on food security

According to Stokes (2008), from 1990 - 2007 global grain yields grew by 1.20% yearly (i.e. less than half of that during the period 1970-1990), showing a reversal of trend in food supply vis-a-vis population growth. The rich countries are not that affected by indigenous food scarcity and price rise because of their unquestionable economic capabilities. In fact though essential, the share of agriculture in the GDP of the OECD countries is insignificant ranging in most countries between 1-3% and often equal to the subsidy and other supports rendered to the rural people. From an inherent sense of nationalism and food security of the country especially for emergent situations, agriculture is over- generously patronized by the respective governments. For most developing countries, however, agriculture is an important obligatory profession and boosting productivity with rising population is a matter of serious concern. Such countries earlier received adequate public support and aids from international agencies but now find the funds drying up considerably (often less than half) and governments themselves are financially very hard pressed. The World Bank lending in agriculture which was $7.7 billion in 1980 was reduced to $2.0 billion in 2004. International Rice Research Institute (IRRI) in the Phillipines, International Maize and Wheat Improvement Centre (CIMMYT) in Mexico and another dozen institutes in Asia, Africa and Latin America, collectively known as the Consultative Group on International Agricultural Research (CGIAR) have suffered serious budget cuts from 6 billion dollar in 1980 to 2.8 billion dollar in 2006; USA, the major country cutting the fund from $2.3 billion to $624 million. The profit seeking transnational corporations have entered the agricultural research section in a very big way so much so that the multinational company Monsanto alone spends seven times as much on agricultural research as the 14 CGIAR institutes taken together (Stokes, 2008).

Many of developing countries have over the recent decades implemented the policies recommended or required by the International Monetory Fund (IMF), the World Bank and World Trade Organization (WTO) and other international agencies but the consequences have not been to the best of their interests. Some countries that were previously self sufficient in food, now import large quantities of food and net food imports are now factual truth for many developing countries, Africa had a surplus of exports in cereals, rice, soybeans and other food products but over the years have shifted towards imports of those products (Sundaram,2010). Following the advice of WB, IMF and WTO a large number of developing countries reduced subsidies to their small holder farmers making their domestic agriculture nonremunerative and people dependent on imports. It may be that subsidies and controls are distortions in free trade but the cost of such distortions needs to be weighed against the benefit of food security to alleviate poverty and hunger. Further, the rich countries have continued all through out to subsidize and protect their farmers and their agricultural subsidies and tariffs have undoubtedly undermined the production in developing countries. Though subsidized food is considered cheap by western standards if is still very high for the poor consumers of the third world and inevitably they will be priced out of market and face starvation. It is, however, true that a section of the people would be there to buy imported food; the majority would go deeper into poverty, and as such, suffer from chronic hunger and malnutrition. It is not difficult to visualize the anti small holder poor farmer strategies of the World Bank, IMF and WTO only to safeguard the interests of the developed countries. Indeed, it was a frank utterance by John Block, a former US secretary of agriculture in 1986 who termed the idea of developing countries feeding themselves," an anachronism from a bygone era" (an outdated idea!), saying they should buy American (!). That was nevertheless more diplomatic than another US secretary of agriculture Earl Butz who rather crudely wanted to use food as a weapon, if necessary.

Food must not be treated like any other commodity as it is vital for the sustenance of life without any alternative whatsoever. Food security for all people in a country must therefore be considered as a basic human right and any attempt to dilute that philosophy should invite all-round condemnation.

Fortunately the stand of the Food and Agriculture Organization (FAO) of the United Nations on the issue has been commendable. The June 2008 food summit in Rome at the peak of the year of global financial and food crisis saw probably the starkest difference between the FAO Director General Jacques Diouf on one hand and the alliance of the Washington based International Financial Institutions, World Bank, WTO and OECD led by the World Bank President Robert Zoellick with the former calling for a renewed commitment to food security while the latter for agricultural trade liberalization as the solution rather than food security (Sundaram, 2010). Diouf strongly criticized the rich country governments for their deliberate failure on providing aids for specific agricultural plans in developing countries (aid reduced from $8 billion in 1980 to $3 billion in 2005), creating a carbon market worth $64 billion in developed countries but not providing funds to prevent deforestation (on an average 13 million hectares annually), providing $11 to 12 billion as biofuel subsidy and diverting 100 million tonnes of cereals from human consumption to biofuels, OECD countries providing $372 billion subsidies for agriculture in 2006, in one country alone (presumably the USA) food worth $100 billion wasted annually, excessive consumption by world's obese costing $20 billion per year and above all reminding the delegates that the world spent a staggering $1.2 trillion on arms purchase in 2002. In any case, there was no call for further trade liberalization in the 2009 food summit which also recognized that food security must be a part of national strategies, and that raising agricultural productivity is the key to food security. The summit also noted that the declines in agricultural investment, research and development and official development aid (ODA) have been key long-term factors contributing to food insecurity as also the recognition of the adverse role of biofuel subsidies and market speculation. In fact, the summit deliberated against the policies of the World Bank and its Washington based allies.

Pope Benedict XVI who attended the summit called for increased access to international markets for products from the poorest countries. Libyan President Gaddafi called for an end to the purchase of African farm land by food importing nations warning that such "new feudalism" could spread to Latin America as well (see box 2.8 : Land grabbing a growing a growing phenomenon) in Human Development Report, 2011, chapter 2, p 39). FAO true to its commitment to eradicate hunger, proposed with the support from Latin America, west Asian and African Nations, the setting up of a time line for the eradication of hunger by 2025. The proposed idea was reportedly rejected by the

USA, the European Union, Canada, Japan, New Zealand and Australia. FAO hoped that the summit would set an agricultural aid target of $44 billion to help farmers in the poorer countries but the donor countries failed to agree on a target for the ODA (Sundaram, 2010).

World Bank's assistance in addressing the constraints to agricultural development in Africa over the period 1991-2006 has been assessed by World Bank's Independent Evaluation Group (IEG). The study's central finding is that agriculture has been neglected by both governments and donor community, including the World Bank.

World Development Report 2008 has been a departure from usual WDRs (World bank's flagship publications) in that if acknowledges policy mistakes on several issues for example regarding the dominant role of transnational corporations, it records "growing agribusiness concentrations may reduce efficiency and poverty reduction impacts" and that such "Concentration widens the spread between World and domestic prices in commodity markets for wheat, rice and sugar (which more than doubled from 1974-1994. A major reason for wider spreads is the market power of international trading companies.

The 2010 world Development Indicators (2010 WDI) of the World Bank providing data on World population dynamics in section 2.1 (p. 64) gives data on world Population in 2008 as 6697 million and the projected population in 2015 as 7241 million along with total population figures under different income categories. We have estimated the percentage of population in 2008 and 2015 under low income group as 14.6 and 15.6 percent for the respective years, the same for middle income group as 69.6 and 69.4 respectively and high income group as 16.0 and 15.3 respectively. In the middle income group there are two subgroups lower middle income with population percentage of 55.3 in 2008 and 55.4 in 2015; that in the upper middle income being 14.2 percent in 2008 and 13.7 percent in 2015. Thus, there is a small but definite increase in the percentage of poor people. The absolute increase in population is, however, noted in all categories (albeit nonuniform); the increase is smaller in high income and upper middle income groups than in low income and lower middle income groups. As poverty, hunger and malnutrition are correlated with economic status of people, the data would confirm that majority of the people in the low income group (around one billion people) are suffering from chronic hunger and around half of the low middle income group (around two billion people) are victims of malnutrition; making a total of around three billion people in the world (about 43% of global population) who are suffering from food insecurity. It is indeed an alarming situation and there is absolutely no alternative to food and nutritional security. Denial of social justice to three billion food insecure people would have colossal repercussions in due course on further augmentation of the almost certain adverse effects of climate change with the passage of time affecting global peace to such an extent that trillions of dollars spent on military armaments could appear as ridiculous as acts of utter insanity.

ACKNOWLDGEMENTS

Professor T. M. Das eminent environmental scientist and founder of the Indian Association of Biological Sciences and founder-editor of Indian Biologist has been instrumental in the publication of this article. About two years back he wanted an analytical review on food and agriculture situation based on current global scenario with due emphasis on India as a special issue of the journal which he has nurtured for nearly four and a half decades. We are deeply indebted to him for his continued encouragement and support in the endeavour.

The authors profusely thank Professor P. N. Roy, eminent economist and former Chairman of the West Bengal State Pollution Control Board, Professor Tarun Kumar Bose, former Director of Research, Bidhan Chandra Krishi ViswaVidyalaya, Mr. Kanti Biswas , a former minister of West Bengal and an expert of human development issues and Dr. R. K. Chattopadhyay, a teacher on mathematical statistics in BIT Mesra, Kolkata Extension Centre for their help in various ways. Professor A. K. Sharma, President of the National Academy of Sciences, India (NASI), and a former General President of the Indian Science Congress Association has rendered valuable advice in the preparation of the manuscript for which we owe our sincere gratitude to him.

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