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Prospects of Feed Crops in India

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Abstract

Animal husbandry is the backbone of Indian agriculture. It provides livelihood opportunities to the farmers (more than 70 per cent of the population) who depend on mixed farming. Animals not only contribute to the household income, but draught power and organic manure as well as many other products. Currently, the emphasis is given to animal production to meet the demands of an increasing human population. Intensive production is being targeted from the enormous livestock population in the country to meet the demands. The estimated requirement of feeds for livestock is short by 64 per cent. Since animal production activities in India are mostly at the household levels of small and marginal farmers, feeding systems are dependent upon the indigenous practices and the requirements are met from the crop and food residues in the system.

The CGPRT sponsored project "Prospects of Feed Crops in South Asia (FEED)", was attempted during the year 2001-2002. The study was initiated to understand the demand-supply gap and identify measures to bridge it, based on the data provided by the Department of Economics and Statistics, Ministry of Agriculture and the Government of India. It is found that most of the coarse cereals are facing decline in area and productivity. It is also found that depending on the demand, productivity and production scenario, it is possible to bridge the gap between demand and supply. Accelerated production activities and policy may control the market so that the farmers receive a better price for their product.

Introduction

The global trends in animal production indicate a rapid and massive increase in the consumption of animal products. It is predicted for 2020 that meat and milk consumption will grow at 2.8 and 3.3 per cent per annum in less developed countries. Meat consumption in the least developed countries will increase from 88 - 188 million tons and developing countries will require 223 million tons more milk. In terms of value, livestock products will equal or exceed products from crops.

India, with only 2 per cent of the worlds land area has 16 per cent of the cattle, 54 per cent of the buffaloes, 5 per cent of the sheep and 21 per cent of the goats in the world. India has a livestock population of 489.7 million, which has been growing at a rate of 1.09 per cent annually (between 1987-1992) (Table 1 and 2).

The livestock population in India is the largest among the countries of Asia and the Pacific. Due to land use changes and livelihood demands there has been wide variations in the growth trends between livestock species. The annual growth rates for different species of livestock are shown as cattle 0.50 per cent, buffalo 1.0 per cent, sheep 1.0 per cent, goats 1.0 per cent, pigs 0.0 per cent and poultry 18.2 per cent between 1988-1992, which further shows a decline in all the species except poultry by 2002 (Table 2). Livestock contributes 6.06 per cent

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to the National GDP. The livestock sector contributes Rs 1,830,000 million to the annual revenue i.e. 32 per cent of the agricultural output, which is 27 per cent. It also provides 70 per cent of the employment in rural areas. The present level of production of animal products (viz, milk, meat, fibre, egg) will have to be augmented in response to growing demands from the human population, which has already crossed the 1,000 million mark. India has shown tremendous progress in milk production (84.456 million tons in 2000-2001 as opposed to 57.96 million tons in 1992) during the past decade but per capita availability (226 g as opposed to 182 g per head) has to not only increase but has to be well within the reach of the population below the poverty line (40 per cent at present) (Table 3).

Table 1. Livestock population - projected estimates*

(in million)

Year	Cattle	Buffaloes	Sheep	Goat	Equine	Camel	Total
2002	215.3	91.3	51.4	129.9	0.5	1.2	489.7
2003	217.6	93.2	51.9	133.1	0.4	1.3	497.5
2004	218.8	94.1	52.2	134.6	0.4	1.3	501.4
2005	219.9	95.1	52.5	136.3	0.4	1.3	505.4
2006	221.1	96.1	52.7	137.9	0.4	1.3	509.5
2007	222.3	97.0	53.0	139.5	0.4	1.3	513.5
2008	223.5	98.0	53.3	141.2	0.3	1.3	517.7
2009	224.7	99.0	53.6	142.9	0.3	1.3	521.8
2010	225.9	100.0	53.8	144.6	0.3	1.3	526.0
2011	227.1	101.0	54.1	146.4	0.3	1.3	530.2
2012	228.3	102.1	54.4	148.1	0.3	1.3	534.5

(* Estimates based on livestock population data from 1950-1992 collected from the Livestock Census, Department of Animal Husbandry and Dairy, Ministry of Agriculture, New Delhi. The figures were projected to 2012 using growth trends).

Table 2. Growth trends in livestock population (% annual growth)

Species	Population (million)			% Annual growth	
	1988	1992	2000	1988-1992	1999-2000
Cattle	193	197	200	0.5	0.2
Buffalo	72	75	79	1.0	0.7
Sheep	52	54	56	1.0	0.5
Goat	105	110	116	1.0	0.7
Pigs	10	10	11	0.0	1.2
Poultry	260	450	1,210	18.2	21.1

Table 3. Projected requirement of milk for domestic demand and export (million tons) (based on the growth trends)

Demands	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Domestic	93.58	95.59	97.5	99.45	101.44	103.47	105.4	107.37	109.34	111.31	113.28
Export @ 5per cent	4.683	4.78	4.88	4.97	5.07	5.17	5.265	5.362	5.459	5.556	5.653
Total	98.263	100.37	102.38	104.42	106.51	108.64	110.665	112.732	114.799	116.866	118.933

Table 4. Projected estimate of annual requirement of concentrate feeds in the decade ((million tons) (based on the standard feeding practices and requirements of different species of livestock))

	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Buffalo	41.43	42.57	43.61	44.64	45.70	46.84	47.88	48.96	50.03	51.11	52.18
Cattle	55.89	57.33	58.45	59.52	60.92	62.14	63.38	64.62	65.87	67.12	68.36
Sheep	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16
Goat	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12
Pigs	1.39	1.47	1.53	1.59	1.66	1.73	1.79	1.86	1.93	1.99	2.06
Equine	0.97	0.98	1.00	1.00	1.01	1.03	1.04	1.05	1.06	1.07	1.08
Poultry	13.75	14.84	15.69	16.59	17.54	18.55	19.48	20.44	21.39	22.35	23.30
Total	113.68	117.44	120.52	123.59	127.09	130.55	133.84	137.19	140.55	143.91	147.27

Source: Authors' calculation.

It is meat and egg production, which is required to be up scaled to meet the increasing human need. A study conducted by Rosegrant *et al*, 1995 shows that while India had a positive balance between the demand and supply for meat and eggs during 1990, by the year 2020 it is going to face a huge deficit, except in the case of egg production.

Demand for feed stuffs and feed crops

The demand has been calculated based on the consumption behaviour and average rate of feeding of concentrates for different categories and species of livestock (Table 4). It shows a growing trend over the next ten years. It is noteworthy that maximum demand is for cattle followed by buffalo and poultry.

This demand does not necessarily show that the animals actually receive the concentrates. This is just an ideal situation. Most of the dry herds, sheep, goats and local breed of animals hardly get the required quantity of animal feed. Considering the estimates of Taneja (1999), it has been found that the deficit is only 47 per cent against this estimate, giving a 64.27 per cent deficit. The consumption of feeds has to increase in view of the emphasis on cross bred herds for milk, poultry and pig production.

To meet the demands of an increasing number of livestock and also their higher productivity, feed resources have to be augmented. Coarse cereals account for about half of the total cereals produced in the world. The five major coarse cereals, viz, maize, barley, sorghum and pearl millet account for about 44 per cent of the total cereals. Of the total coarse cereals, maize accounts for almost three quarters and barley accounts for 15 per cent. Sorghum and millets account for 11 per cent. India's production of these cereals is stagnating at around 30 million tons, which is less than 3 per cent of the world's production. At present, the country faces a net deficit of 61.1 per cent in green fodder, 21.9 per cent in dry crop residues and 64 per cent in feeds.

Livestock production and consumption

Taneja (1999) remarked, "Livestock contributed 68.6 million tons of milk, 28.2 billion eggs, 44.3 million kg of wool and 4.14 million tons of meat (1992 basis). The value of the output from the livestock at the current price was 897 billion Rs (1996-1997) excluding draught power valued at 45-95 billion Rs (in terms of fuel equivalent). Livestock production is primarily a small farm production system characterized by low input - low output, except poultry and to some extent, dairying with cross bred cows and buffaloes, which are not only sustainable but provide good economic returns. Around 80 per cent of the livestock are in marginal, small and medium holdings, having 53 per cent of the operated area. The majority of livestock owners are below the poverty line. Average herd size per farm is 3.7 heads of cattle and buffalo. Small

ruminants are mostly reared under nomadic (30 per cent) and sedentary (70 per cent) systems. Pig production is mostly under a scavenging system, practiced by the weaker section of society. Poultry production is reasonably organized, 50 per cent of poultry meat and 56 per cent of the eggs are produced under an intensive production system".

The expected rise in milk yield may be sufficient to meet the demands for milk and milk products of the growing population. However, the projected deficits of animal meat will require larger emphasis on boosting their productivity through breed improvement and feeding. The increased poultry farming will require added input of grains in the feed.

Aquaculture and inland fisheries

India is gifted with a 1,311 km long coastal line. During the year 2000-2001, India exported 440,473 tons of seafood worth US$ 1.4 billion. The exports are expected to increase to US$ 2.5 billion by 2005-2006 from an initial level of 15,732 tons worth Rs 3.9 crores in 1961-1962. The shrimp farming industry, which picked up in 1980 but slowed by 1990 has again started picking up. The world's average per capita per year availability of fish is 2.1 kg per person.

The global aqua feed tonnage for the year 2000 was considered as 15 million mt. Of this, 90 per cent was in Asia, 5 per cent in Europe, less than 2 per cent in south America, 2 per cent in North America and less than 1 per cent in Africa, the Middle East and Oceanea. In fish feed, soy meal and full fat soya are being incorporated as opposed to fish meal. The use of oil meals is likely to grow. In India, the use of fish feed and its quantity of use is difficult to estimate since it is mostly in the unorganized sector. There appears to be little competition from the livestock industry since the most common use of food grains is as broken rice or wheat flour. Although the use of oil cakes/meals is increasing, it is still at a slower pace.

The feed crops

The major components of animal feed are maize, sorghum, pearl millet, minor millets and barley, besides the broken grains of rice and wheat and also the wheat and rice bran that is derived from the processing of wheat and pulses from the mills. During the past 50 years, the share of production of coarse grains in the total grain production has been declining. For maize however, it has been showing a steady increase up to 1970 after which, it almost stabilized with a slight increase after 1990. This has been mostly due to the increase in the irrigation potential, which has contributed to a change in land use. Many crop species are combined as minor millets viz, finger millet/ragi (e*leusine coracana*), little millet (p*anicum miliare*), kodo millet (*paspalum scrobiculatum*), fox tail millet (s*etaria italica*), barnyard millet (*echinochloa frumentacea*), proso millet (p*anicum miliaceum*), savan millet (e*chinochloa colona*). They are still grown in many parts of the country.

Feed crops and feed ingredients

Coarse cereals

About half of the total world production of cereals is coarse cereals (Table 5). In India, it is only 15.6 per cent, of which about 2 per cent is utilized for feed.

Table 5. Significance of coarse cereals

		India	USA	World
Total cereals mt	Cereals total	188.43	332.44	1,872.1
	Feed	1.77	164.1	655.1
% feed to total cereals		0.94	49.37	34.99
Wheat + Rice mt	Wheat + Rice	159.02	68.8	988.67
	Feed	1.20	7.72	104.6
% feed to total cereals		0.75	11.22	10.58
Coarse cereals mt	Coarse cereals	29.41	263.64	883.46
	Feed	0.57	156.4	550.4
% feed to total cereals		1.94	59.32	62.3
% coarse to total cereals		15.61	79.3	47.19
% four coarse cereals to total cereals*		15.61	78.56	43.82

* Four major coarse cereals are barley, maize, millets and sorghum.
Maize, sorghum and millets are the major components of the coarse cereals in India with their 10.78, 8.7 and 8.47 million tons production.
Source: FAO Bulletin of Statistics, Vol. 1 No.2-2000.

Table 6. Growth rates of major crops in the world and India between 1961-1999

Commodity	Growth rates						Yield (kg/ha)	
	Area		Production		Yield			
	World	India	World	India	World	India	World	India
Wheat	0.08	1.90	2.41	5.24	2.33	3.28	2,761	2,583
Rice	0.58	0.59	2.53	2.70	1.94	2.10	3,888	3,007
Barley	0.04	-4.13	1.28	-1.96	1.24	2.26	2,393	1,882
Maize	0.74	0.61	2.79	2.28	2.04	1.66	4,358	1,655
Millets	-0.61	-1.28	0.09	0.46	0.71	1.76	748	722
Sorghum	-0.32	-1.45	0.63	0.23	0.95	1.70	1,426	826
Coarse cereals	0.20	-1.18	2.13	0.68	-1.89	1.88	3,032	995
Total cereals	0.08	0.15	2.15	2.82	-2.02	2.66	3,098	2,308

Source: FAO Bulletin of Statistics, Vol. 1 No. 2-2000.

Coarse cereals production variability was very high (15 per cent or more) compared to other cereals (less than 10 per cent).

Maize

Maize is a top ranking cereal in terms of global productivity. It is second to wheat in total production and has great significance as a human food, animal feed and industrial products. It is also called the queen of cereals and occupies a 20 per cent area of the cereals. Maximum production of maize comes from the USA (48 per cent) followed by China (23 per cent). India contributes only 2 per cent to world maize production. Global maize demand is increasing rapidly (50 per cent increase) (Table 6). It is expected that the demand for maize will surpass the demand for rice and wheat globally.

Maize occupies a 26 per cent area in India and contributes 41 per cent of production out of the three coarse cereals, maize, sorghum and pearl millet. In India, it is cultivated in both seasons with a maximum in the rainy season (kharif) but the yield in winter (rabi) is more (Singh, 2001). It is expected that the hybrid technology and winter maize have a high potential for production improvement. It is primarily consumed for poultry feed (40 per cent), human food (36 per cent), livestock feed (12 per cent), starch (10 per cent) and seed (2 per cent). The quality protein maize (QPM) has very high potential for improving the nutritional balance in humans and animals.

Production of maize has remained almost stagnant at around 10.8 million tons from 1996-1997 onwards. The growth of production of maize, which increased by 2.33 per cent per annum during the eighties accelerated to 2.92 per cent per annum during the nineties. The

marginal improvement in the rate of growth of output was due to the expansion in area from (-) 0.1 per cent per annum during the eighties to 0.74 per cent per annum during the nineties. The growth of productivity, on the other hand, has slightly decelerated from 2.42 per cent to 2.16 per cent between these two periods. Front line demonstrations and field trials conducted by the ICAR are reported to have realized yields of maize up to 6.31 t per hectare. The average yield of maize at 1.73 t per hectare has reached 13.5 mt maize on a 6.5 million ha area (2.08 t/ha)

Quality Protein Maize

- High content of lysine and tryptophan and essential amino acids which are deficient in normal maize kernels
- Better balanced amino acid composition in grain
- Kernel, taste and appearance like normal maize
- Good agronomic performance
- Tolerance to major insect pests and diseases.

Sorghum

Sorghum is the most important cereal crop for poor people and grown for food, feed and industrial products. It was grown over an area of 18 million ha with 9 million tons produced in the late 1960s, in contrast to the present area of 10.4 million ha with an almost similar level of production (8.3 mt). It is important to note the current sorghum scenario in the country where the rabi sorghum area (5.64 million ha) has become larger in proportion (54 per cent) than the 4.76 million ha (46 per cent) area left under kharif. Sorghum is also grown for forage in northern India over an area of 2.6-3.0 million ha (Table 7).

Table 7. Area (million ha) and grain yield (kg/ha in parenthesis) of *kharif* and *rabi* sorghum in major *rabi* sorghum growing states

Season	Maharashtra	Karnataka	Andhra Pradesh	Total
Kharif	1.96 (1,317)	0.41 (1,391)	0.33 (725)	2.7 (1,256)
Rabi	3.18 (550)	1.52 (667)	0.44 (655)	5.14 (594)

Source: Authors' calculation.

The compound growth rate of area, production and yield between the two periods indicates a negative growth rate in area of *kharif* crop but the overall yield has always shown a positive rate of 1.78 per cent per annum. This rate slightly declined between 1980-2000 (Table 8).

Table 8. Compound growth rate of sorghum area, production and yield

Season	Period	Area	Production	Yield
Kharif	1967-1968 to 1999-2000	-2.352	-0.146	2.259
	1980-1981 to 1999-2000	-4.262	-2.294	2.058
Rabi	1967-1968 to 1999-2000	-0.636	0.685	1.329
	1980-1981 to 1999-2000	-0.932	0.521	1.462
Total	1967-1968 to 1999-2000	-1.612	0.136	1.781
	1980-1981 to 1999-2000	-2.800	-1.343	1.501

Source: Authors' calculation.

Use as animal feed

Sorghum

Sorghum grain can be nutritionally, a better feed due to its high protein and fibre content. Bagasse of sweet sorghum, bio-enriched with microorganisms can be a good cattle feed, as the demand for feed is rising at a rate of 4 per cent per annum. Indian white grain sorghum has a very low or zero tannin content in contrast to brown or red sorghum from the other countries. In poultry feed, maize can be replaced by sorghum to the extent of 50 per cent without altering the egg laying potential (81.1 per cent) and broiler weight. If inclusion of sorghum in feed is maintained at 20 per cent, 3 million tons of sorghum will be required for this purpose alone (Rana *et al*., 2001). Cattle feed manufacturers buy sorghum during July-August when its price is relatively low compared to maize but in October, maize prices fall and they switch over to maize.

Barley (hordeum vulgare)

Barley is an important coarse cereal in India. Barley is a crop useful for food grains, fodder, malt breweries, pearl barley, livestock feed and poultry feed. The barley grain contains 12 per cent protein, 1.4 per cent fat and as such, is not less than wheat in its nutritional quality (Singh, 1999). The area under barley cultivation in the country declined from 3.4 million ha in 1967-1968 to 1.8 million ha in 1980. After 1990 it has declined further to 0.85 million ha. This represents slightly more than 1 per cent of the total area under barley in the world.

The level of productivity has increased from 1 t/ha in 1960 to 2 t/ha presently. In the global context it is still much lower. It is considered that barley is a crop most fitted to dry climates, poor quality irrigation, drought conditions, poor fertility and saline - sodic conditions. Barley, along with other coarse cereals like pearl millet, ragi etc has lost much ground to wheat and other commercial crops during the course of the green revolution. Its cultivation is normally taken up by poor farmers whose land holdings are small and of low productivity, mostly in the states of Rajasthan, Haryana, M.P. and U.P.

Pearl millet (bajra)

Production of bajra, after increasing from 5.38 million tons in 1995-1996 to 7.87 million tons in 1996-1997 declined to 7.64 million tons in 1997-1998 and to 7.03 million tons in 1998-1999. The estimate for 1999-2000 was 5.58 million tons i.e. a decline of 20.6 per cent from the preceding year.

The rate of growth in area under bajra which declined by 1.0 per cent per annum during the eighties, further declined by 1.23 per cent per annum during the nineties. Nevertheless, production increased from 1.15 per cent per annum to 2.35 per cent per annum because of an acceleration in the growth of yield from 2.18 per cent per annum during the eighties to 3.63 per cent per annum during the nineties. This may be attributed to large scale adoption of hybrid varieties by the farmers in recent years as the percentage of area under the high yielding bajra has increased from 47 per cent in 1986-1987 to 67 per cent in 1996-1997, the latest year for which the information is available.

Minor millets (ragi)

Production of ragi, after declining from 2.5 million tons in 1995-1996 to 2.09 million tons in 1997-1998 had rebounded to a peak of 2.81 million tons in 1998-99 i.e. a rise of 17.4 per cent over the preceding year. Considering the longer term, the production of ragi declined from

2.78 million tons during 1980-1981 and 2.42 million tons during 1990-1991 to 2.42 million tons during 1998-1999, resulting in a trend rate of growth of (-) 0.47 per cent per annum during the eighties and (-) 0.15 per cent per annum during the nineties. The reason for this was the decline in area from 2.62 million hectares during 1980-1981 to 2.28 million hectares during 1990-91 and further to 1.75 million hectares during 1998-1999 so that the trend rate of growth of area under the crop was (-) 1.37 per cent per annum during the eighties and (-) 2.71 per cent per annum during the nineties. The average productivity of this crop has however, been higher than jowar and bajra. Its yield has increased from 1,063 kg per hectare during 1980-1981 to 1,100 kg per hectare during 1990-1991 and to 1,377 kg per hectare during 1998-1999, or an acceleration in the trend rate of growth of yield from 0.91 per cent per annum during the eighties to 2.63 per cent per annum during the nineties.

Materials and methods

Principles of economic modeling have been used to study the area, production and yield functions of these crops. *An economic model is merely a theoretical construct or analytical frame work composed of a set of assumptions from which conclusions are derived.*

Three steps are involved in model building.

- In the first step, the model builder must select the variables and relationships among them that seem most pertinent to the problem to be attempted. This step produces the economic model, which contains a set of assumptions regarding the relevant variables and the relationships among them.
- Secondly, apply the necessary corrections to the model and derive a theoretical/logical conclusion.
- Thirdly, test the conclusion against the real phenomenon. If the observed conclusions do not fall in agreement with the derived data then a new conclusion must be derived.

Analytical framework

An increase in the livestock numbers and a growing human population in developing countries has to depend upon the land use and management options for their sustenance. Three primary sources of growth as regards to livestock are prevailing in the developing countries. These are, expansion in livestock numbers, increased intensity of range and pasture utilization and better use of feed concentrates and agricultural by-products, and higher output of meat, milk or eggs per animal through improved management, breeds, and technologies. The area and production statistics for India are based on the crop cutting experiments laid in different agro-ecological zones of the country. The agricultural field experiments are laid at the different centres incorporating the trend statistics about the area, production, imports, exports and consumption through sampling methodologies. Statistics on different crops give us an idea about the supply and demand level of the crops to compete with the growing population trends. The DES (Directorate of Economics and Statistics, Ministry of Agriculture and cooperation, Govt. of India) provides yield estimations in respect to principal crops of food grains, oilseeds, sugarcane, fibres etc. which contributes about 87 per cent of the agricultural output. These estimates of crop production are obtained by multiplication of area estimates by corresponding yield estimates.

Model formulation

Trends were formulated on the basis of growth trends, by taking the moving averages on three years of the last 50 years data records (Agricultural Statistics at a Glance 2001, Directorate of Economics and Statistics, DAC, Ministry of Agriculture, Govt. of India, 1950-1951 to 2001-2002). The compartments of data trends were decided on the basis of scatter diagram analysis. A three year base for moving average was taken to incorporate the effect of probability of drought. The moving average formed graphs and based on trends in the last data compartment have been selected for model formulation. Last compartment data was considered for model formulation as it was assumed to include the latest affecting factors including Government policies in recent years. Before the formulation process, it was assumed that the current trends of acreage as well as production would have a strong association with the previous year's data, since the current status is very much dependent on the previous year's status.

The demand has been formulated on the basis of calculation that the crop produce shall be consumed (production-exports) as per the Indian agricultural policy (Ministry of Agriculture, Govt. of India, 2000) for coarse cereals, which indicates that 87.5 per cent is consumed as food, 5 per cent as feed for the animal and poultry requirement, 5 per cent is to be kept as a seed source and 2.5 per cent as waste.

The following models have been formulated:

Acreage function

$$\mathrm{Ln}(\mathrm{At}) = a + b\mathrm{Ln}(\mathrm{At}-1),$$

where At = area under production at time t-th year,

$\mathrm{A}(t-1)$ = area under production at $(t-1)$ th year,

Production function

$$\mathrm{Ln}(\mathrm{Pt}) = a + b\mathrm{Ln}(\mathrm{Pt}-1) + c\mathrm{Ln}(\mathrm{At}-1),$$

where Pt= production at time t-th year,

$\mathrm{P}(t-1)$ = production at $(t-1)$ th year, and

$\mathrm{A}(t-1)$ = area under production at $(t-1)$ th year,

Export function

Export has been worked out considering it a function of time and has been derived on the basis of past records available in Jena, *et al*. 2001. The export trend was obtained through performing scatter diagram analysis and the model of the type Ln(Export at base 1993=1) = a + b Ln(t) + Ln(t^2) , where t = time, a, b are constants and are to be determined through simple regression analysis.

The crop-wise models evolved are:

Maize

Maize acreage function

$$\mathrm{Ln}(\text{Area at time t}) = a + b\,\mathrm{Ln}(\text{Area at time t}-1)$$

Coefficients	Estimates	t- statistics
a	-.10258	-0.43693
b	1.057528	10.26747

R^2=0.937734 Adj. R^2= 0.928839

It has been found that the estimated function explains 93 per cent variation in the maize yield. There is a 1.05 per cent increase in the maize area over the previous year's acreage. This shows a significant increase in area under maize.

Maize production function

$$\mathrm{Ln}(\text{Production at time } t) = a + b\ \mathrm{Ln}(\text{Production at time } t-1) + c\mathrm{Ln}(\text{Acreage at time } t-1)$$

Coefficients	Estimates	t- statistics
A	-.18164	-0.42085
B	1.12959	2.965531
C	- 0.01894	-0.16311

R^2= 0.96971 Adj. R^2= 0.959613

The estimated model for maize production (mt) explains 97 per cent of the value of maize production. The production of a particular year increased by a 1.13 per cent increment over the previous year. The contribution of the previous year's acreage was not significant.

Maize export function

$$\mathrm{Ln}(\text{Export},\ t = 1993 = 1) = a + b\,\mathrm{Ln}(t) + c\,\mathrm{Ln}(t^2)$$

Coefficients	Estimates	t- statistics
A	-2.91735	-1.52107
b	3.239748	2.947476
c	-0.40691	-3.03019

R^2=0.696659 Adj. R^2= 0.544989

The estimated function for maize export with respect to time (1993=1) explains 70 per cent variation. The estimated model evolved was quadratic in nature and shows that the export has a 3.23 per cent increase over the previous export value but adjusted by a significant decrease of 0.4 per cent. However, based on the previous 10-year export trends, the export projection of maize in the near future is almost negligible.

Based on the above models, the projections for the future status of maize acreage and production for the coming 10-years (2002-2012) have been made.

The acreage function projection model explains 93.77 per cent variation in the area whereas elsewhere it explains 42.07 per cent, when estimated with respect to ratio of unit price of maize to paddy and previous year acreage. The projections made for maize production with respect to maize production for the previous year along with the acreage could explain 96.90 per cent variation in current maize production. Compared to elsewhere, when the ratio of production to urea, production and acreage in previous years were used as predictor variables it could explain only 54 per cent variation in the production for the same data. This shows the degree of model fitness to the data. Therefore, the model adopted is well suited for Indian perspectives.

The expected annual growth (per cent) of area was less (around 2 per cent) compared to production, which may go up to 7 per cent in 2012. This may be due to the proper potential of this crop being utilized.

Pearl millet (bajra)

Acreage function

$$\text{Ln}(\text{Area at time t}) = a + b\,\text{Ln}(\text{Area at time t} - 1)$$

Coefficients	Estimates	t- statistics
a	0.2321	0.5089
b	0.89649	4.55063

R^2=0.65308 Adj. R^2= 0.62155

The estimated function could explain 65 per cent variation in the area with bajra. The area under bajra has a significant decrease (0.9 per cent) over the previous year's bajra acreage.

Production function

$$\text{Ln}(\text{Production at time t}) = a + b\,\text{Ln}(\text{Production at time t} - 1) + c\,\text{Ln}(\text{Acreage at time t} - 1)$$

Coefficients	Estimates	t- statistics
a	4.78939	3.76455
b	-0.4073	-1.62216
c	-0.9134	-1.8969

R^2= 0.40846 Adj. R^2= 0.2605

The bajra production estimation model explains 41 per cent variation, which indicates that for this crop both the predictors (bajra production and acreage at the previous year) have an insignificant contribution in the estimation. This may be due to policy adopted by the Government of India (GOI) from time to time.

Export function

$$\text{Ln}(\text{Export at time t}) = a + b\,\text{Ln}(\text{Export at time t -1})$$

Coefficients	Estimates	t- statistics
a	1.25784	6.73143
b	0.18922	1.92435

R^2= 0.64931 Adj. R^2= 0.47397

The estimation function for the export of bajra explains 65 per cent variation in the exports. This may be due to the market and the export policy. On the basis of the above derived estimation equations for bajra acreage and production, the projection of bajra production and their different kinds of use, as per the policy of GOI, is mentioned in the reports.

Sorghum (jowar)

Acreage function

$$\text{Ln}(\text{Area at time t}) = a + b\,\text{Ln}(\text{Area at time t} - 1)$$

The estimation model for the acreage of jowar explains 99 per cent variation in the area. For this crop the percentage increase over the previous year was 1.07 per cent but adjusted by constants resulting in a minor decreasing trend.

Coefficients	Estimates	t- statistics
a	-0.19872	-3.22858
b	1.066323	45.756
R^2= 0.991476	Adj. R^2= 0.991002	

Production function

$$\text{Ln}(\text{Production at time } t) = a + b \text{ Ln}(\text{Production at time } t-1) + c \text{ Ln}(\text{Acreage at time } t-1)$$

The prediction model for jowar production explains 93 per cent variation in jowar production. The jowar acreage for the previous year has a significant contribution in prediction as compared to the previous year's production. However, this crop shows that there could be a decrease in the coming years.

Coefficients	Estimates	t- statistics
a	-0.07382	-0.30225
b	0.302552	1.429128
c	0.660797	3.952104
R^2= 0.92564	Adj. R^2= 0.909115	

Export function

$$\text{Ln}(\text{Export at time t}) = a + b \text{ Ln}(\text{Export at time t - 1})$$

The export policy of GOI and the production and domestic consumption of jowar for the previous year is responsible for the poor estimation in which the estimation model could explain only 39 per cent variation in the exports.

Coefficients	Estimates	t- statistics
a	0.790913	0.721344
b	0.678602	1.775328
R^2= 0.386638	Adj. R^2= 0.263965	

The projections of jowar acreage and production were made on the basis of evolved estimation models. It has been observed that the acreage and the production are both decreasing considerably. Based on previous trends, exports are also decreasing.

Barley

Production function

$$\text{Ln}(\text{Production at time } t) = a + b \text{ Ln}(\text{Production at time } t-1)$$

The estimation model for barley acreage explains 86 per cent variation in the area. The area shows a slight increasing trend over the previous year. This shows a reduction in acreage for the projected years.

Coefficients	Estimates	t- statistics
a	0.115905	2.997303
b	0.734915	9.700764
R^2= 0.862518	Adj. R^2= 0.853352	

The acreage was derived by taking the national yield average of the current year for barley.

Export function

$$\text{Ln}(\text{Export at time t}) = a + b\,T\,(1995 = 1)$$

The barley export estimation shows 79 per cent R^2, while taken as a exponential trend (base 1995=1). As the production of barley declines, exports also decline.

Coefficients	Estimates	t- statistics
a	-0.91008	-1.61126
b	-0.55984	-2.71446

R^2=0.786513 Adj. R^2= 0.67977

The projection of barley in the coming decade shows that it may become a less prioritized crop with dismal growth unless and until the Government of India takes some steps to encourage this crop as a feed source for animal and poultry besides its use for the brewery.

Ragi (eleusine coracana)

Acreage function

$$\text{Ln}(\text{Area at time t}) = a + b\,\text{Ln}(\text{Area at time t} - 1)$$

The prediction model used taking the previous year area under ragi, could explain 93 per cent. The area under this crop also declines significantly from the previous year.

Coefficients	Estimates	t- statistics
a	0.15381	2.813426
b	0.704944	7.953899

R^2= 0.926756 Adj. R^2= 0.912107

Production function

$$\text{Ln}(\text{Production at time t}) = a + b\,\text{Ln}(\text{Production at time t} - 1) + c\,\text{Ln}(\text{Acreage at time t} - 1)$$

The estimation model for ragi production explains 72 per cent variation in the production. Acreage for the previous year was the significant predictor variable in the estimation.

Coefficients	Estimates	t- statistics
a	0.73079	0.486679
b	-0.15452	-0.41116
c	0.486679	2.536539

R^2= 0.724842 Adj. R^2= 0.587262

Export function

$$\text{Ln}\left(\text{Export at time t}\right) = a + b\ \text{Ln T}\left(1993 = 1\right)$$

This estimation function explains 72 per cent variation in ragi exports. The exports show declining trends in the coming years. The projections made for this crop show that the acreage remains almost the same but the production increases slightly. Exports also show declining trends, as almost all of the coarse cereals are scientifically constituted as animal feed products.

Coefficients	Estimates	t- statistics
a	3.98036	5.522167
b	-0.587401	-3.173712

R^2= 0.715757 Adj. R^2= 0.644696

Comparison of the models

From an Indian perspective, the change in public policy is made according to the needs of the people in terms of five-year plans. The present estimates for acreage and production have been compared with the models for acreage and production studied elsewhere by applying them on the same set of data (Table 9).

Table 9. Model comparison with model formulated elsewhere (R^2 value)

Crop	Acreage		Production	
	w. r. to previous year acreage (Current study)	w. r. to ratio of unit price of crop to paddy and acreage of the previous year (Study elsewhere)	w. r. to production and acreage of the previous year (Current study)	w. r. to unit price of urea to maize, production of previous year and time (Study elsewhere)
Maize	93.77	42.71	96.97	53.88
Bajra	65.30	22.57	40.85	49.30
Jowar	99.15	88.11	92.56	49.30
Barley			86.25	37.59
Ragi	92.68	22.58	72.48	57.74

Source: Authors' calculation.

The models formulated in the study were more accurate than those tried elsewhere. They were derived through standard regression analysis (Draper and Smith, 1981). However, the models studied in this report were compared with those tried elsewhere, incorporating the prices of the respective crops in an Indian context as per the report of the "Commission for Agricultural Costs and Prices" shown for the crops sown during the 2000-2001 season on the same set of data. The export estimation was made on the basis of the last 10 years data records (Jena, *et al*., 2001). Maximum accuracy of the model was obtained in most of the cases except in one case (bajra production) where the gap in explaining the variation was too small. Therefore, the models formulated are better from an Indian perspective.

Pricing policies

Real prices of coarse cereals were stagnant after the mid seventies but that of rice and wheat declined. Coarse cereal prices declined at a rate of 1.48 per cent per annum while that of rice and wheat declined by 1.6 per cent and 1.97 per cent respectively. These differences in

growth rates should be seen in the light of low or negative growth of coarse cereal production and high growth in the production of rice and wheat. With an increase of 3-5 per cent per annum in the latter cereals and little growth in coarse cereals, it may be said that price is maintained at a level that is keeping pace with demand, or demand is adjusting to price. However, for rice and wheat, very high growth has led to a decline in the real price. As a result of these factors, the price gap between the coarse cereals and wheat and rice reduced gradually. Coarse cereal prices generally remained lower than wheat and rice prices.

The price variability of coarse cereals was compared to the heavily supported wheat and rice. It was observed that prices of coarse cereals fluctuated more than wheat, rice, oil seeds, pulses and cotton. The variability in millet price was 35.56 per cent compared to 14.66 for oil seeds, 25.09 for cotton and 25.06 per cent for wheat.

International price comparison indicates that the price of coarse cereals was much lower in the world market with the exception of millets. This means that as WTO processes are implemented, Indian coarse cereals could face competition from other countries that may have comparative advantage. If however, subsidies in western countries are removed or lowered, India may have comparative advantage. Otherwise, farmers will be left with less profitable crops and only subsistence farmers could survive the adverse effects of globalization. This is because of the use of family labour on their farms. Farmers with a marketable surplus would face decline in income.

Consumer price behaviour

The prices of these commodities have been increasing but the major component of the oil cakes and oil meals in the concentrate determine price behaviour. In the case of most of the small dairy units, household production often replaces the expensive concentrates. Since most of the coarse cereals are priced low, they are used in an even higher proportion of the home made concentrate mixtures.

The consumer price behaviour of the commodities shows great diversity in the case of coarse grains as opposed to the other cereals. The changes in the support price during the past 10 years shows an almost similar trend for coarse cereals and paddy (Table 10). In the case of wheat, it has shown a higher change indicating the pressure on the growers and the input costs. The percentage change in yield shows a better situation for coarse cereals except sorghum. However, the change in return per ha is greatest for ragi followed by wheat. The return from other coarse cereals is in no way less than paddy, but still emphasis on crops is determined by the easy availability of inputs like water for irrigation, fertilizers, good soils etc.

Table 10. Changes in support prices (MSP) of different commodities and in gross returns

Commodity	MSP (Rs./kg)		% Change	Yield (t/ha)		% Change	% Change in return/ha
	1990-91	2000-01		1990-91	2000-01		
Paddy	2.05	5.10	148.8	2.588	2.904	12.2	179.21
Wheat	2.15	5.80	169.8	2.216	2.615	18.01	218.34
Sorghum	1.80	4.45	147.2	0.793	0.795	0.21	147.74
Bajra	1.80	4.45	147.2	0.638	0.736	15.36	185.20
Ragi	1.80	4.45	147.2	1.100	1.428	29.86	221.00
Maize	1.80	4.45	147.2	1.515	1.743	15.05	184.43
Barley	1.80	4.30	138.9	1.596	1.905	19.34	185.08

Source: Authors' calculation.

Supply of feed and feed crops

Production behaviour

In the previous pages, where the estimates of production have been calculated through the model, we find that the per cent annual expected growth for maize has a rising trend for both area and production. It has been found that the production increase at the base year 2002 is expected to double, the area will also increase. The production behaviour of sorghum gives a reverse trend to maize. For bajra, both area and production show a declining trend. Barley too is showing decline in both area and production.

Producer price behaviour

The existing price trend of coarse cereals in the domestic and international market indicates that wheat and rice are the preferred commodities as a staple, domestically as well as globally, whereas, coarse cereals will provide cutting edge competition for cattle feed and industrial uses. A proposal relating to the use of ethanol, to the extent of 5 per cent with petrol as a fuel, is under the consideration of the Govt. of India. This may induce firmness in the price of coarse cereals, provided that the manufacture of ethanol from coarse cereals is found to be cost effective in comparison to other sources. Yet the production of coarse cereals needs to be regulated to such an extent that these crops are competitive in trade as well as to the farmers.

Production response to market forces

In the case of coarse cereals, before discussing the issue we should try to understand the habitat requirement of these crops, climate preference, soil type, availability of irrigation and other inputs. The high rate of variance in productivity of coarse cereals is yet another factor determining increase/decrease in the acreage. However, it is more interesting to consider the market wholesale price index and the minimum support price offered by the Government (Table 11). The market price for coarse cereals is higher compared to the support price but the uncertainty of the market behaviour/trends does not attract the farmers to take the risk compared to crops like paddy and wheat. The changes in land use and land cover due to increasing sources of irrigation and urbanization/projects also determines the crop choice. The present emphasis on crop and land use diversification has a potential for boosting the production of these crops if the market and the processing industry are supportive. It is again emphasized that these crops, with their potentials, should attract the attention of the planners.

Table 11. Minimum support price and market whole sale price (Rs/100 kg) of commodities in 2000-2001

Price	Paddy	Wheat	Barley	Maize	Bajra	Sorghum	Ragi
Market price	530	725	800	720	600	700	750
Support price	510	620	450	445	445	445	445

Source: Authors' calculation.

Development of production technology

There are certain key points for higher productivity of coarse cereals:

- Selection of improved, high yielding varieties suitable for specific soil and moisture conditions.
- Use of proper sowing time and planting geometry. Use of seed drills to get line sowing and proper seed rate. Treating the seed for fungicides before sowing. In heavy rainfall areas, transplant it using 20 day old seedlings. Assure the use of biofertilizers i.e., 3 g

Azospirillum per kg seed at the sowing time. Apply recommended fertilizer doses. Irrigate the crop at critical stages of water stress.

- Keep the plot weed free. Attend thinning 20 days after sowing. One to two interculturing and one hand weeding 30-35 days after sowing.

These are some tips to assure high productivity.

Production projection

While the productivity of most of the coarse cereals has shown similar change compared to rice and wheat, area has been declining under most of these crops with the exception of maize. The only scope for their growth is through high level research and development input. The percentage change in productivity between 1990-1991 to 2000-2001 of most of these crops shows that for ragi and barley the change has been more than for paddy and wheat. Still the production of these crops has not increased due to the decline in acreage. It is expected that by the use of hybrid technology, grain production can be enhanced in the case of maize and sorghum. These two crops have the potential for meeting the increased demands. Barley, as a crop, needs emphasis for its potential utilization to meet the demand from industry and also livestock production as a feed crop.

The emphasis on proper land use and water conservation being given now, may support the crops more suited for the degraded lands and poor soils with lesser irrigation water requirement. Under such policy initiatives, coarse cereals have a future.

Measures for closing supply and demand gaps

The current requirement of animal feed is estimated at 117.44 million tons for all species of livestock, including poultry, and is increasing at a rate of 2.62 per cent. The present level of production is estimated at 41.96 million tons thus showing a deficit of 64.27 per cent (Planning commission discussion papers 2001). This gap is likely to continue. In another estimate, Taneja (1999) has shown a 47 per cent shortage of the concentrates. Grains and concentrates contribute only 3 per cent to the total feed resources in the country. Taneja also remarked that only lactating animals receive better feeding through the supplementation of byproduct concentrates (oilcake, bran, chunnies etc.). Sheep and goats are generally maintained on grazing and browsing and no concentrates are fed. Farmers neither have the knowledge nor feed to feed their livestock as per nutrient requirements. The present level of availability is 42 million tons of raw material that is processed/made available to the livestock industry. It is also estimated that, of this availability, 25 per cent is milled as compound feed and the rest fed, as such, to the animals by the farmers. In India, the annual production of compound feed by CLFMA members is around 3.2 million tons while other lesser organized sectors and cooperatives account for around 4-5 million tons. With the increasing potential in the poultry and dairy sector, the future demand for compounded feed is expected to grow at 12 per cent.

With growing concern for quality animals and high productivity, feed use is likely to increase. It was understood that substantial deficits can be made up with the use of non-conventional concentrates of agro industrial and forest origin, which was estimated at 11.02 million tons in 1990-1991. Farmers may also increase their use of other grains like wheat, broken rice and others for feeding the productive animals. The National Dairy Development Board and Indian Dairy Corporation are making efforts to increase the level of production of milk and also the animal feeds to support them. Many state dairy corporations and the milk societies also make efforts to provide feed to the members.

Dairy production in India is becoming more organized but meat production is still disorganized and dispersed. It is due to this reason that the estimates of demand and supply are based on population trends.

Research and development

Upstream

Indian Council of Agricultural Research, New Delhi has a number of institutes to address research on these crops. Some of them are as follows:

Commodity	Research Institute Involved
Maize	Directorate of Maize Research, IARI Campus, Pusa, New Delhi
Sorghum	National Research Centre for Sorghum, Hyderabad
Barley	AICRP on Barley Improvement, DWR Karnal
Sorghum	AICRP on Sorghum Improvement, Hyderabad
Millets (Ragi)	AIC Small Millets Improvement Project, UAS, Bangalore
Maize	AICRP on Maize, DMR, New Delhi
Pearl millet	AICRP on Pearl Millet,, RAU, Jodhpur
Coarse cereals	AICRP on Under Utilized Crops, New Delhi

Downstream

Besides those at the Central Government and State Government level there are Directorates of Minor Millets Development. These crops are also researched in the State Agricultural Universities in different states. The Zonal Agricultural research stations under the State Agricultural Universities also provide region specific research backup on these crops. The growing poultry industry in the organized sector and also pigery will demand maize grain and also the millets which will have a larger scope in times to come. Since these often come under the organized sector as industry, research and development support for CGPRT crops will also accelerate.

International trade

The sustainability of coarse cereals in the agricultural economy of the country, it is speculated, depends largely on increasing capital intensity and export potential for competitiveness in the agricultural market of the country and the world. To put it another way, linkage to the world export market will make this sector more competitive and sustainable and will lift it out of the current condition whereby production is stagnant.

During the past decade, sorghum and pearl millet have shown a consistent export performance whereas the performance of maize, barley, ragi and cereals have only picked up from 1993, 1995, 1992 and 1992 respectively. Even though the percentage share of total coarse cereal exports in the total export performance of the country is not significant, it can not be denied that the export of coarse cereals in absolute terms recorded increasing growth over the years.

Farmer participation in feed crop development

Potentials

Most of the feed crops are grown under subsistence farming conditions in the dry lands that are dependent upon the monsoon rains. The soil conditions preferred are mostly the

degraded and marginal agricultural lands. Thus, they are subjected to the vagaries of the monsoon and also poor soil fertility. These soils also suffer due to micronutrient deficiencies, which limits the production. Maize is an exception since it also covers high productive lands in the upper Gangetic alluvial plains. When considering the growing demand for feed crops and also their use as nutri-cereals in the diet of human beings, the growth potential is very high. In the case of maize, the growth is phenomenal. Based on this and the feed structure, the availability scenarios have been tested. As per the guidelines of the Ministry of Agriculture (5 per cent of the grains), 5 per cent of all coarse grains + 20 per cent of maize, as per the Planning Commission paper, the projections are presented. It shows that it is possible to produce 25.4 million tons of feed from cereals (with 20 per cent maize) during the year 2002. When oilseed cakes are added, 43.8 million tons can be easily supplied. Another supply from non-edible oil cakes and meals makes up 11 million tons, thus making the total up to 55 million tons annually. Considering other factors of feed requirement for the livestock it may be possible to meet the demand, which can be about 66 million tons annually. However, the requirements for increased productivity will demand better nutrition for which efforts have to be continued.

Constraints

Farming technology is still very primitive and a lack of improved varieties are major constraints in many coarse cereal growing areas. The cropping systems and crop mixtures to support high production are not known to farmers. The uncertain environmental conditions and lack of contingency planning are the major constraints. A poorly developed market and lack of support price are yet more constraints. These crops deserve special treatment since the area used to grow them is decreasing in response to high productive crops and also the increase in better inputs including irrigation.

Advantages

These crops require a low input and therefore can be cultivated with less investment. The low rainfall, poor soil fertility and the uncertain monsoon can be an advantage to growing these crops. Their increased production can also support better nutrition for humans and livestock. The growing emphasis on nutri-cereals may bring further advantage to the farmers. Alternate uses for sorghum and other millets can also diversify the market and assure better market prices for these commodities.

Problems

Proper policy implementation for the development of the market and support for the farmers are the major problems facing the farmers. The slow growth of research emphasis for the development of high yielding varieties is yet another problem.

Response to market development

Stability in market prices has to be assured in order to make these crops more remunerative to the farmer. Import restrictions to safeguard the interest of coarse cereal growers in the country is important when considering the comfortable level of production of these crops. If the customs duty on imports of these crops is raised, the domestic market prices can be controlled and undesirable imports can be reduced. Thus, proper execution of market intervention mechanisms in consonance with administered prices (MSP) in respect to coarse cereals on a par with wheat, rice, pulses, oil seeds, cotton and jute is a must to provide a better market and also promote its production growth by the farmers.

Response to manufacturing development

The total availability of feed is 42 million tons, however the installed capacity of the feed mill is only 5.1 million tons, which is actually processing just 3.2 million tons. The other cooperative factories manufacture 4-5 million tons of balanced concentrates. Other units manufacture about 2.5 million tons of feed. The demand for feed milling is growing at an annual rate of 12 per cent. If this growth is emphasized, the production sector can be assured of a remunerative price. This has been observed in the state of Gujarat for crops like groundnut and coarse cereals.

Conclusions and recommendations

Demand for coarse cereals in India has been shrinking with some exceptions like maize. The consumer is becoming used to superior cereals. However, a class of consumers is sticking to coarse cereals and therefore price is stagnant as supply is adjusting to the demand. Production has kept pace with demand on declining areas under coarse cereals, mainly because of high-yielding varieties. Continued supply of high-yielding varieties helped reduce the cost of production and this helped coarse cereals (pearl millet) to be able to compete with cash crops like groundnut. World export prices (F.O.B.) are much cheaper than prices in India. The major use of coarse cereals in the world is for animal feed as opposed to food use in India. The above conclusions lead to the following policy needs:

- Promote coarse cereals for feed and other uses.
- In view of food security concerns, provide coarse cereals at subsidized rates to the poor. Otherwise, the poor farmers and labourers will suffer the most if supply declines and price increases (Bapna, 2001).
- Investment in Research and Development on these crops should increase. Greater investment in the development of coarse cereal HYV, possessing resistance to drought and insect-pests, to reduce the cost of production is needed and diversification of the cultivation of these crops in the areas rendered surplus.
- Negotiate with coarse cereal exporting countries under the WTO Agreement on Agriculture for a reduction in subsidies given by them to their farmers, and
- Provision of supply of coarse cereals at subsidized rates to Below Poverty Line (BPL) families to ensure access to food as a measure of food security. Sorghum is grown for food, cattle fodder, feed and also provides raw material for the manufacture of a wide range of industrial products.

Improving sorghum productivity

- Area under Kharif sorghum has declined sharply whereas area decline in Rabi sorghum is comparatively slow. A wide range of HYVs of sorghum have been bred to cater the requirement of food, fodder, feed and industrial usages. Special HYV sorghum has been bred for forage. Improved sorghum production technology modules have been developed for different agro-climatic regions/sorghum based cropping systems through sustained research over the years. Community drier is a newly found and most eco-friendly IPM measure for the control of grain moulds in sorghum.
- Every part of the sorghum plant could be gainfully utilized for food and non-food usage. Moulded grain is preferred for the manufacture of potable alcohol. Sorghum malt, starch, alcohol, liquid glucose, High Fructose Syrup (HFS), malto-dextrins for

use in the baking Industry, ethanol, jaggery and adjuncts need to be promoted on a large scale.

- A check on the sorghum trade through non-regulated markets by the Agriculture Produce Market Committee to ensure the payment of a legitimate market price to sorghum growers.
- The introduction of summer cultivation sorghum to make the crop more competitive in terms of grain quality and productivity in Peninsular India.
- Large-scale popularization of inter-cropping of sorghum with pulses/oilseeds through under development incentive programmes.
- Introduction of sorghum cultivation in rice fallows.
- Sorghum is inherently produced through organic farming. Hence, suitable quality standards and provision of quality certification mechanisms shall be evolved for organically produced commodities as a measure of consumer preference and creating consumer awareness.
- Appropriate market intervention for the procurement of sorghum at administered prices shall be ensured to be on par with wheat and rice.
- Emphasis on the export of sorghum grain for cattle feed.
- Assured production of quality seeds of public bred sorghum cultivars and effective quality control of sorghum seeds sold in the market.

Improving maize production

- Maize crop should be accorded special status and separated from coarse cereals for strategic development.
- The minimum support price of maize should be made more remunerative.
- Food subsidy on maize shall also be provided, like wheat and rice on the supply of maize through PDS.
- Promotion of the cultivation of Quality Protein Maize (QPM) and single cross maize hybrids through Mission Mode.
- Enhancement of the Seed Replacement Rate (SRR) in maize by way of fast track seed production of HYV's of maize in the States of Bihar, Gujarat, Madhya Pradesh, Rajasthan and Uttar Pradesh, where the productivity of maize is less than the National average.
- Involvement of the Indian Maize Development Association (IMD) in strategic development of maize for encouraging "Contractual farming in maize" and export of value added products of maize.
- Renovation and upgrading of the machinery and capacity expansion of existing "Starch Plants' with appropriate fiscal support like Mission on Cotton.

Cultural and nutrient management

- Imbalance and inadequacy of fertilization of coarse cereals is omnipresent due to their inherent cultivation in marginal and degraded soils.
- Maize and barley are more susceptible to micro-nutrient deficiency, sorghum and pearl millet are moderately susceptible and ragi is least susceptible.
- Integrated use of 2.5 to 5.0 t/ha of FYM or City Compost supplements zinc requirement by 25-50 per cent while 10-15 t/ha FYM is adequate to correct the micro-nutrient deficiency in coarse cereal.

- Coarse cereals do not respond to copper and molybdenum application in Indian conditions.
- Regular application of 20-30 kg/ha of sulphur before sowing significantly enhances the productivity of most coarse cereals.
- Diversification of agriculture is receiving priority in view of a decline in productivity due to depletion of ground water resources and the agenda of WTO on agriculture.
- Optimum use of micro-nutrients ensures the quality of the produce as well as reduces the toxicity of trace elements like selenium in forages on problem soils.
- The use of multi micro-nutrient mixtures should be restricted to certain crops with expert's recommendations to save extra costs and reduce heavy metal pollution in the soil and environment.

Post harvest management

- Adaption of coarse cereals to poor habitats and resources, and a lack of awareness of the food value of coarse cereals among urbanites/irrigated areas are responsible for the limited progress of these crops.
- All of the cereal grains are plant seeds and, as such, contain a large centrally located starchy endosperm encapsulated with hull, bran and embryo or germ usually near the bottom of the grain.
- Hull in grain is indigestible by man, bran often being dark coloured repels consumer preference, germ, being rich in oil, is enzymatically active sometimes producing rancidity under certain conditions. This needs to be removed through post-harvest management.
- Development of coarse cereal based nutri-foods, particularly for the urban population by ICAR/CFTRI/Private sector food companies is required, as is the development of improved mills for the milling of coarse cereals.
- Research on storage and enhanced shelf-life of coarse cereals.
- Research on eco-friendly packaging technology for coarse cereal products.
- Starchy and proteinous endosperm of grains offer food value which is achieved by proper milling and pre-milling operations. Proper post-harvest management is crucial to improve food value and nutritional aspects as well as induce trade competitiveness in the commodity.

Environmental issues and crop diversification

- Coarse cereal cultivation is confined to arid and semi-arid regions across the globe. Arid climate is characteristic of low rainfall, high summer temperatures with very low winter temperatures and associated with high wind velocity and high evapo-transpiration.
- A high tree canopy with a perennial grass canopy on the soil surface neutralizes the harshness of the climate and creates ecological equilibrium for the survival of living beings. Multi-purpose trees are an integral part of arid and semi-arid farming systems and the livelihood of the people of these regions. Cyclic droughts often occur in arid and semi-arid regions. Improvement in pearl millet productivity in crucial arid districts namely, Bikaner, Barmer and Jaisalmer of Rajasthan which is in the range of 25-157 kg/ha on 1.32 million ha could be achieved to the level of the productivity of pearl millet in East Rajasthan with plausible diversification of this area by introducing novel agroforestry systems. Research is needed for creating competitiveness in coarse

cereals. Development of IPM modules for coarse cereals with greater emphasis on cultural practices.

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