An Empirical Study on Water Resources Development & Management and its Repercussions on Indian Agriculture

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Abstract

India is endowed with a rich and vast diversity of natural resources. Water is one of the most essential natural resources for sustaining life. Its development and management play a vital role in agriculture production. Integrated water management is vital for poverty reduction, environmental sustenance, and sustainable economic development. With rapid growing population and improving living standards the pressure on our Water Resources is increasing and per capita availability of Water Resources is reducing day by day. Water availability per person is dependent on population of the country and for India, per capita water availability in the country is reducing due to increase in population. The average annual per capita water availability in the years 2001 and 2011 was assessed as 1816 cubic meters and 1545 cubic meters respectively which has further reduced to 1486 cubic meters cubic meters in the years 2021. The paper presents availability and demands of water resources in India as well as describes the various issues and strategies for developing a holistic approach for sustainable development and management of the water resources and its implication on Agricultural Production of the country.

Keywords: Water Resources; Net Irrigated Area; Net Sown Area; Foodgrains; Growth Rate; Production; Yield.

1. Introduction

India has an agriculture-based economy having 2.45 % of the total land area of the world, 16% of the world population and is endowed with about 4% of its water resources. Water is one of the Pancha Tattva, the five prime elements of which everything is made, four others being Earth, Air, Fire, and Sky. Of these, Water is the key nurturer, without which most life, including human life, cannot survive. Water, which sustains life on earth, is an invaluable natural resource. Earth is the only planet in the entire solar system which supports life, because it contains water. With increasing urbanization

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and water demand, the per capita water availability in the country has declined by almost 20% in the last two decades and is likely to decline by another 20% by 2050, making India a water-scarce country. About 71 per cent of the surface of the earth is covered with water, but only about 3 per cent of the total water on the earth is freshwater. The assured irrigation water supply is utmost importance for food security. The total ultimate irrigation potential of the country is estimated about 140 M ha.

In India, 82% of total operational holders are small and marginal farmers having only 39% of the total operated area, whereas 18% medium and large farmers occupy 61% of the area operated by them. The ultimate irrigation potential in the country using both the surface and ground water sources is of the order of 140 M ha comprising of 75.83 M ha from surface water sources and 64.17 M ha from ground water sources. The total Ultimate Irrigation Potential (UIP) of the country stands at about 140 M ha. The share of Minor Irrigation is higher by 22.96 M ha as compared to that of Major & Medium Irrigation. Ground Water contributes more than 78% of the total ultimate potential through minor irrigation. Uttar Pradesh and Bihar are the two largest States in terms of potential due to Major & Medium Irrigation Projects.

According to one estimate of water reserves on earth quoted by the Food and Agriculture Organization (FAO) of the United Nations, the total water reserve on earth is about 1.4 billion km^3. However, fresh water constitutes a very small proportion of this enormous quantity available on earth. It is only about 35 million km^3 or just 2.5% of the total volume and the remaining is saline water. A large fraction of the fresh water, about 24 million km^3 or 68.7% is in the form of ice and permanent snow cover in the mountainous regions, the Antarctic and Arctic regions and another 30.1% is present as ground water. About 0.3% is available in lakes, rivers and 0.9% in soil moisture, swamp water and permafrost atmosphere.

2. Concepts and Definitions

Definition 2.1 (Net Area Sown). *This represents the total area sown with crops and orchards. Area sown more than once in the same year is counted only once.*

Definition 2.2 (Gross Cropped Area). *This represents the total area sown once and/or more than once in a particular year, i.e. the area is counted as many times as there are sowings in a year. This total area is also known as total cropped area or total area sown.*

Definition 2.3 (Net Irrigated Area). *It is the area irrigated through any source once in a year for a particular crop.*

Definition 2.4 (Gross Irrigated Area). *It is the total area under crops, irrigated once and/or more than once in a year. It is counted as many times as the number of times the areas are cropped and irrigated in a year.*

Definition 2.5 (Operational Holding). *All land which is used wholly or partly for Agricultural production and is operated as one technical unit by one person alone or with others without regard to the title, legal form,*

size or location.

Definition 2.6 (Operational Holder). *An Operational holder is the person who has the responsibility for the operation of the Agricultural holding and who exercises the technical initiative and is responsible for its operation. He may have full economic responsibility or may share it with others. The operational holder may be Individual/Joint/ Institutional.*

Definition 2.7 (Operated Area). *Area includes both cultivated and uncultivated area, provided part of it is put to Agricultural production during the reference period.*

3. Methodology

Secondary data has been used from the published reports and datasets. The following formula was used to calculate the **compound growth** rate:

$$Y_n = Y_0(1+r)^n$$

where, Y_n is projected variable value, Y_0 is initial variable value, r is compound growth rate of variable in proportion, n is period.

$$R = \left[\left(\frac{Y_n}{Y_0} \right)^{\frac{1}{n}} - 1 \right] * 100$$

where R is Compound percentage Growth Rate.

Three Year Moving Average

$$Y_{t+1} = \frac{Y_t + Y_{t+1} + Y_{t+2}}{3}$$

where Y_t is variable (area sown, production or yield), and t is period, say, $t = 0, 1, 2. \ldots$

Projection: Least Square Technique has been applied for the following linear model:

$$Y = a + bX$$

where Y is Food grains production, a is constant, b is regression of Y on X,

$$X = \begin{cases} 1, & \text{for 1994-95;} \\ 2, & \text{for 1999-2000 \& so on.} \end{cases}$$

4. Findings and Discussions

Water Resources Management is one of the key factors for development of Agricultural production and related areas where water requirement is essential. Water is essential for survival of human beings, plants, animals, and fisheries. The requirement of water is increasing due to increase in population, living standards, domestic use, irrigation, industry and environmental conservation. Therefore, water

management is very essential to meet the demands in various sectors. Water resources management is one of the key factors in development of agricultural production and related area in order to attain self-reliance in food security and also development of Agro-based industries so that employment opportunity can be enhanced.

Table 1, presents the three yearly moving averages of area sown, production and yield for food grains. It is seen that production has been increased from 51.21 M Tones in 1950-51 to 307.09 M Tones in 2020-21. The area sown has also increased to 128.56 M ha during 2020-21 from 98.91 M ha in 1950-51. The yield level has been 675 kg per ha during 1950-51 which has gone up to 2372 kg per ha during 2010-116. Growth rates have been estimated for different periods. The production is having positive growth rate for all the periods. The highest growth rate in production (5,71%) and area sown (1.75%) was observed during 1950-51 to 1960-61. In case of yield, the highest growth rate (4.02%) was observed during 1980-81 to 1990-91 and lowest (0.27 %) during 1950-51 to 1960-61. The area under irrigation has also increased from 18.20% during 1950-51 to 54.32% during 2020-21.

| Year	Production M Tones	Growth rate per annum	Area Sown M ha	Growth rate per annum	Yield Kg per ha	Growth rate per annum	% Area Under Irrigation
1950-51	51.21		98.91		675		18.20
1960-61	80.47	5.71	116.21	1.75	693	0.27	19.00
1970-71	104.36	2.97	123.5	0.63	845	2.19	24.10
1980-81	124.2	1.90	127.01	0.28	977	1.56	29.87
1990-91	171.94	3.84	125.49	-0.12	1370	4.02	35.81
2000-01	206.49	2.01	122.31	-0.25	1688	2.32	43.97
2010-11	240.63	1.65	124.25	0.16	1935	1.46	48.57
2020-21	307.09	2.80	128.56	0.35	2372	2.36	54.32

Table 1: Three Years Moving Average of Production, Area and Yield of Food grains

Table 2, presents the moving averages of sown area and irrigated area. It is seen that Net Sown area has been increased from 135.71 M ha in 1950-51 to 142.45 M ha in 1991-92 and then decline to 139.20 M ha in 2018-19. The Gross Sown Area has the positive trends and increased to 201.30 M ha in 2018-19 from 156.39 M ha during 1961-62. The Net Irrigated area has also increased to 70.89 ha in 2018-19 from 25.14 M ha during 1961-62. Growth rates have been estimated for the different periods. Net Irrigated area and Gross Irrigated area both are having positive trends during all the periods.

However Net sown area has positive trends except during 1991-92 to 2001-02. and 2011-12 to 2018-19 and Gross sown area also showing positive trends except during 1991-92 to 2001-02. The highest growth rate was observed of the order of 0.25 % for Net sown area during 1961-62 to 1971-72 and 2.69% in case of Net irrigated area during 1971-72 to 1981-82.

Year	Net Sown Area M ha	Growth rate per annum	Gross Sown Area M ha	Growth rate per annum	Net Irrigated Area M ha	Growth rate per annum	Gross Irrigated Area M ha	Growth rate per annum
1961-62	135.71		156.39		25.14		28.80	
1971-72	139.04	0.25	164.38	0.51	31.49	2.53	38.56	3.39
1981-82	140.72	0.12	174.04	0.59	39.97	2.69	51.01	3.23
1991-92	142.45	0.12	184.56	0.60	49.39	2.36	65.21	2.78
2001-02	138.00	-0.31	182.41	-0.12	55.35	1.21	75.87	1.63
2011-12	140.83	0.21	195.91	0.74	63.78	1.52	88.61	1.68
2018-19	139.30	-0.16	201.3	0.39	70.89	1.59	102.21	2.19

Table 2: Three years moving average of Sown Area and Irrigated area
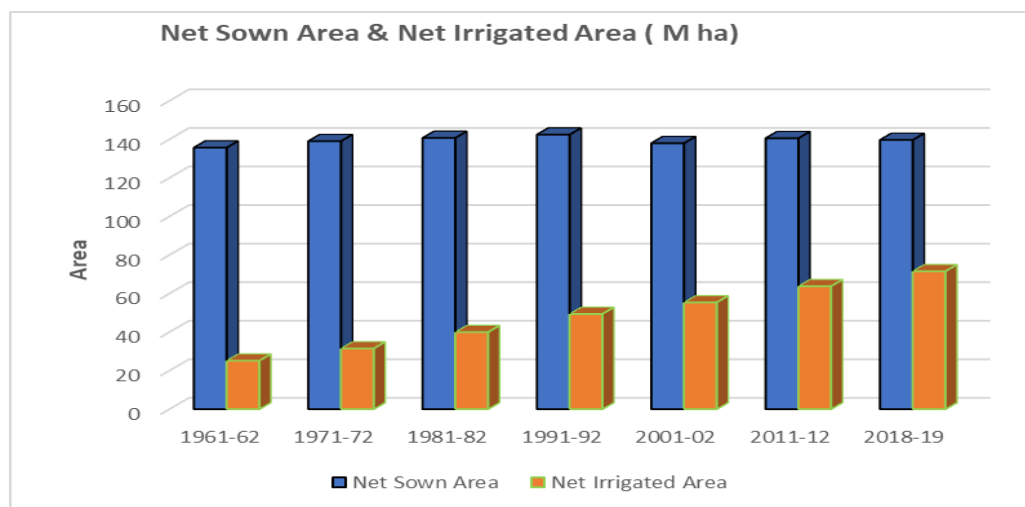
In the survey, the data were collected for the five major size groups of operational holdings, viz., marginal (below 1 ha.), small (1 - 2 ha.), semi-medium (2 - 4 ha.), medium (4 -10 ha.) and large (10 ha. and above). In India, 82% of total operational holders are small and marginal farmers having only 39% of the total operated area, whereas 18% medium and large farmers occupy 61% of the area operated by them. The ultimate irrigation potential in the country using both the surface and ground water sources is of the order of 140 M ha comprising of 75.83 M ha from surface water sources and 64.17 M ha from ground water sources.

Table 3, presents the total Numbers of Operational holdings during different Agricultural Censuses. It is seen that the number of operational holdings has been consistently increasing from 1980-81 to 2010. The total number of operational holdings in the country has increased from 88.88 million in 1980-81 to 138.35 million in 2015-16. The highest percentage share in 2015-16 was observed in marginal category (68.45) followed by small (17.62%), semi-medium (9.55%), medium (3.80%) and large category (0.57%).

Year → Size Group ↓	1980-81	1985-86	1990-91	1995-96	2000-01	2005-06	2010-11	2015-16
Marginal (below 1 ha)	50122 (56.39)	56147 (57.79)	63389 (59.44)	71179 (61.58)	75408 (62.88)	83694 (64.77)	92826 (67.10)	100251 (68.45)
Small (1 - 2 ha)	16072 (18.08)	17922 (18.45)	20092 (18.84)	21643 (18.73)	22695 (18.92)	23930 (18.52)	24779 (17.91)	25809 (17.62)
Semi Medium (2 - 4 ha)	12455 (14.01)	13252 (13.64)	13923 (13.06)	14261 (12.34)	14021 (11.69)	14127 (10.93)	13896 (10.04)	13993 (9.55)
Medium (4 -10 ha)	8068 (9.08)	7916 (8.15)	7580 (7.11)	7092 (6.14)	6577 (5.48)	6375 (4.93)	5875 (4.25)	5561 (3.80)
Large (10 ha and above)	2166 (2.44)	1918 (1.97)	1654 (1.55)	1404 (1.21)	1230 (1.03)	1096 (0.85)	973 (0.70)	838 (0.57)
All Size	88883	97155	106637	115580	119931	129222	138348	146454
Figures in brackets indicates %								

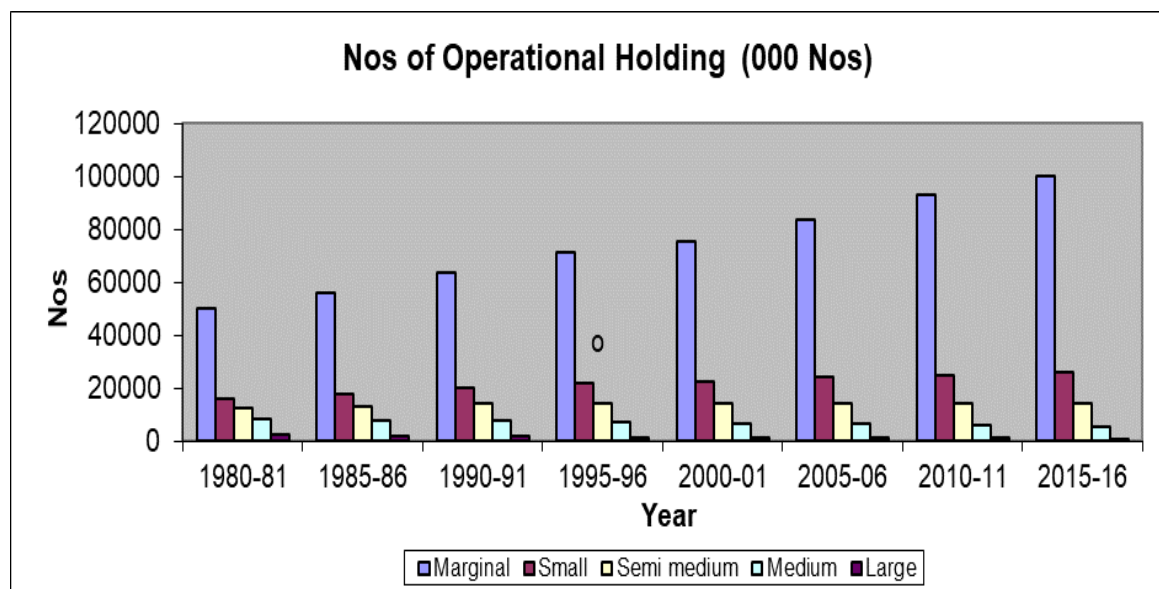Table 3: Number of Operational Holdings (000 Nos)

Table 4, presents the total operated area during different Agricultural Censuses. It is seen that the operated area which was 163.80 M ha in 1980-81 marginally increased over the Census up to 165.5 million ha in 1990-91 and thereafter decreased to 157.82 M ha in 2015-16. The small and marginal holdings constituted 86 percent in 2015-16 against 74 percent in1980-81 and the operated area at 47 percent in the 2015-16 as against the corresponding figure of 26 percent in 1980-81. The semi-medium and medium operational holdings were 13 percent with the operated area at 44 percent in 2015-16. The corresponding figure for 1980-81 was 23 percent and 51 percent. The large holdings were only 0.6 percent of total number of holdings in 2015-16 with a share of 9 percent in the operated area against 0.85 percent and 23 percent respectively in 1980-81.

Year → Size Group ↓	1980-81	1985-86	1990-91	1995-96	2000-01	2005-06	2010-11	2015-16
Marginal (below 1 ha)	19735 (12.05)	22042 (13.39)	24894 (15.04)	28121 (17.21)	29814 (18.70)	32026 (20.23)	35908 (22.50)	37923 (24.03)
Small (1 - 2 ha)	23169 (14.14)	25708 (15.62)	28827 (17.42)	30722 (18.81)	32139 (20.16)	33101 (20.91)	35244 (22.08)	36151 (22.91)
Semi Medium (2 - 4 ha)	34645 (21.15)	36666 (22.28)	38375 (23.19)	38953 (23.85)	38193 (23.96)	37898 (23.94)	37705 (23.63)	37619 (23.84)
Medium (4 -10 ha)	48543 (29.64)	47144 (28.65)	44752 (27.04)	41398 (24.34)	38217 (23.97)	36583 (23.11)	33828 (21.20)	31810 (20.16)
Large (10 ha and above)	37705 (23.02)	33002 (20.05)	28659 (17.32)	24160 (14.79)	21072 (13.22)	18715 (11.82)	16907 (10.59)	14314 (9.07)
All Size	163797	164562	165507	163355	159436	158323	159592	157817
Figures in brackets indicates %								

Table 4: Area of Operational Holdings (000 ha)
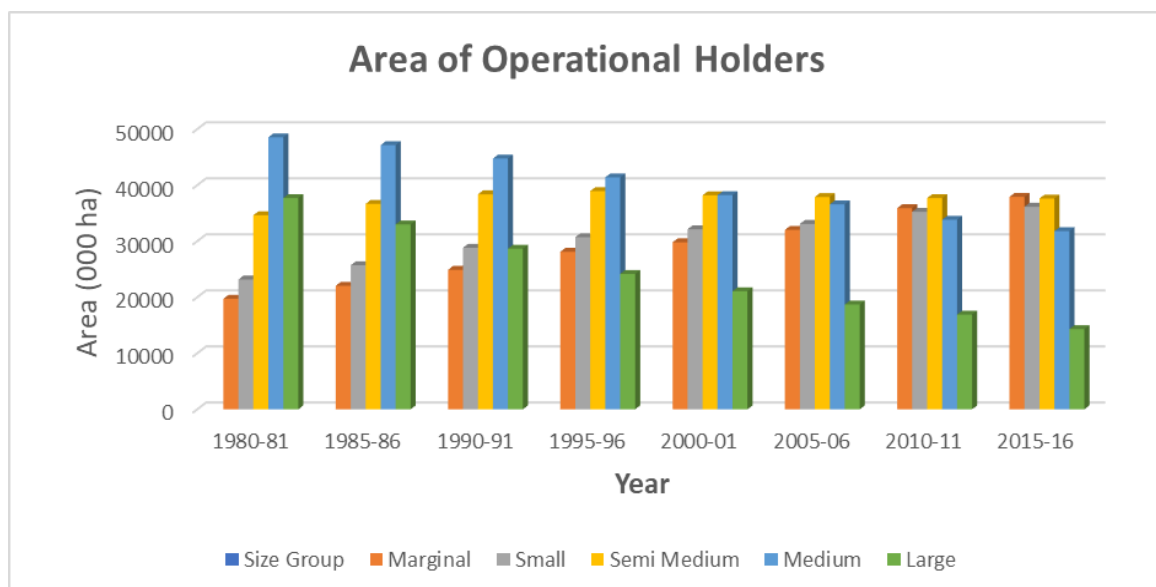
There has been significant development in water resources sector in the post-independence era to meet the food and fiber requirements of the people and accelerated economic growth. The irrigation facilities have increased productivity. The irrigated area in the country has reached in 2018-19, 51% of the net sown area after 75 years of independence. The green revolution has benefited only in the irrigated area in the state of Punjab, Haryana, U.P. etc., but in the country 49% area is still un-irrigated and depend on the mercy of irregular and unpredictable rain.

The break-up of net sown area and net irrigated area is given in Table 5. It is seen that the All-India percentage to Net Irrigated area to Net sown area is observed around 51% % during 2018-19. The highest % of NIA to NSA is observed in Punjab (99%) followed by Haryana (82 %), Uttar Pradesh (91%), and Uttar Pradesh (87%).

S. No.	States / UT's	Net Sown Area (NSA)	Net Irrigated Area (NIA)	% of NIA to NSA
1	Andhra Pradesh	6049	2796	46.22
2	Arunachal Pradesh	234	55	23.50
3	Assam	2723	366	13.44
4	Bihar	5167	3115	60.29
5	Chhattisgarh	4679	1565	33.45
6	Delhi	22	22	100.00
7	Goa	128	16	12.50
8	Gujarat	10302	4233	41.09
9	Haryana	3600	3273	90.92
10	Himachal Pradesh	542	117	21.59
11	Jammu& Kashmir	713	329	46.14
12	Jharkhand	1281	231	18.03
13	Karnataka	10664	4032	37.81
14	Kerala	2034	404	19.86
15	Madhya Pradesh	15205	11349	74.64
16	Maharashtra	16943	3169	18.70
17	Manipur	446	73	16.37
18	Meghalaya	255	101	39.61
19	Mizoram	146	16	10.96
20	Nagaland	384	118	30.73
21	Odisha	4006	1092	27.26
22	Puducherry	15	13	86.67
23	Punjab	4119	4111	99.81
24	Rajasthan	17778	8283	46.59
25	Sikkim	77	15	19.48
26	Tamil Nadu	4582	2565	55.98
27	Telangana	4660	2210	47.42
28	Tripura	255	87	34.12
29	Uttar Pradesh	16538	14392	87.02
30	Uttarakhand	648	323	49.85
31	West Bengal	5248	3107	59.20
31	ALL INDIA	139443	71578	51.33

Table 5: State-wise details of Net Irrigated Area, Net Sown Area 2018-19 (in 000 ha)

The following Table 6, presents the projected Number of holdings and area operated for 2025-26, 2030-31 and 2035-36. The least square model has been used for projection. It is seen that the estimated Number of holdings will be 161.6 Million in 2025-26, 169.51 Million in 2030-31 and 177.41.5 Million in 2035-36. The operated area has been estimated of the order of 155.13 M ha, 152.68 M ha and 151.23 M ha in 2025-26, 2030-31, and 2035-36 respectively.

	2025-26	2030-31	2035-36
No. of holdings (Million)	161.60	169.51	177.41
Operated Area (M ha)	154.13	152.68	151.23

Table 6: Projected Number of Holdings and Operated Area

Table 7, presents the projected Sown area and Irrigated area for 2025-26, 2030-31 and 2035-36. It is seen that the projected Net Sown area will be 138.95 M ha in 2025-26, 138.39 M ha in 2030-31 and 137.83 M ha in 2035-36. The Net Irrigated area has been estimated of the order of 75.15 M ha, 78.95 M ha and

82.74 M ha in 2025-26, 2030-31 and 2035-36 respectively.

	2025-26	2030-31	2035-36
Net Sown Area (M ha)	138.95	138.39	137.83
Gross Sown Area (M ha)	203.16	205.87	208.57
Net Irrigated Area (M ha)	75.15	78.95	82.74
Gross Irrigated Area (M ha)	109.41	115.92	122.43

Table 7: Projected Sown Area, Irrigated Area

Table 8, presents the projected area sown, production and yield for Foodgrains for 2025-26, 20 30-31 and 2035-36. It is seen that the production has been estimated of the order of 317.27 M Tones in 2025-26, 341.60 M Tones in 2030-31 and 365.94 M Tones in 2035-36. The area will be 129.14 M ha in 2025-26, 130.66 M ha in 2030-31 and 132.18 M ha in 2035-36. The projected yield will be 2458 kg per ha, 2628 kg per ha and 2797 kg per ha in 2025-26, 2030-31 and 2035-36 respectively.

	2025-26	2030-31	2035-36
Production (M Tones)	317.27	341.60	365.94
Area (M ha)	129.14	130.66	132.18
Yield (Kg per ha)	2458	2628	2797

Table 8: Projected Area, Production and Yield for Foodgrains

Table 9, presents the projected per capita net availability of foodgrains for 2025, 2030 and 2035. It is seen that the estimated per capita net availability of foodgrains will be 478 grams per day in 2025,481 grams per day in 2030 and 485 grams per day in 2035. Whereas projected per Capita net Availability of foodgrains per Annum will be 174 Kg in 2025, 176 kg in 2030 and 177 kg in 2035.

	2025	2030	2035
Per Capita net Availability of foodgrains per day (Grams per day)	478	481	485
Per Capita net Availability of foodgrains per Annum (Kg per year)	174	176	177

Table 9: Projected per Capita net availability of Foodgrains

Per Capita water Availability is presented in Table 10. The total water availability is about 1869 cubic metre. The per capita water availability of water has been reduced from 5177 cubic metre in 1951 to 1820 cubic metre in 2001 and it is likely to reduce to about 1341 cubic metre by 2025 and further 1140 cubic metre in 2050 due to increase in population.

Year	Population(in Million)	Per capita water availability(in cubic metre)
1951	361	5177
2001	1027	1820
2016	1299	1439
2025(Projected)	1394	1341
2050 (Projected)	1640	1140

Table 10: Projected per Capita Water availability

5. Conclusion

Water is one of the most essential natural resources for sustaining life and it is likely to become critically scarce in the coming decades, due to continuous increase in its demands, rapid increase in population and expanding economy of the country. In view of the existing status of water resources and increasing demands of water for meeting the requirements of the rapidly growing population of the country as well as the problems that are likely to arise in future, a holistic, well planned long-term strategy is needed for sustainable water resources management in India. To meet the targeted production, we have to manage the existing water resources and other related inputs such as fertilizer, pesticides, seed, and credit to farmers, crop insurance and latest technology in optimal manner**.**

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