WATER BUDGETING OF MADHYA PRADESH

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Message

The state of Madhya Pradesh is in the process of an accelerated development in the field of agriculture. Continuous Krishi Karman awards are the evidences of this fact. Water is the most crucial input/resource for the agriculture and therefore a comprehensive understanding of water availability, its distribution and demand in all parts of the state is the key to continue and increase this pace. At the same time agriculture sector is facing the challenges of climate change, depleting ground water and suitable change in crops as well as cropping pattern.

In order to combat with this situation water budget of the state provides data to prepare strategies and planning for sustainable agricultural production in the state.

It is the fortune of state that it receives a good amount of rainfall with an average of 917 mm, contributing a ground water recharge of 35700 ham and filling 22 major, 90 medium and more than 5000 minor reservoirs. Proper budgeting of water-resource on district basis is an important task under taken by Soil and Water Engineers of the College of Agricultural Engineering, Jabalpur. This is in line of in Prime Minister's / Nation's mission of doubling the income of farmers by 2022.

The water budget will be useful in crop selection, efficient water management and its effect and response on associated inputs in light of appropriate water utilization.

The water budget prepared for the state shows that the eastern part of the state needs a water resource development where surface methods of irrigation can be used. In western part water is scares and it has to be used with precision and accuracy.

There are three districts in M.P. which have excess water as per budget computed. They are Balaghat, Umaria and Mandla where available water is 143 to 333% more than total requirement at present. Special attention should be paid to these districts.

I congratulate the team for this good work in the interest of the farmers of the state and hope planners, research workers, extension workers and users will be benefited by this publication and jointly the goal will be achieved.

Care of drops give pearls, I wish all drops to be converted in pearls (grain).

P.K. Bisen
Vice-Chancellor
JNKVV, Jabalpur

Preamble

Water an essential input of agriculture circulates naturally and perpetually in cyclic nature. Therefore, its occurrence varies to a great extent with space and time. For efficient budgeting of water its availability and distribution shall be organized. Water budget is necessary for proper planning of agriculture as it is the most water intensive activity.

Efficient and effective water budgeting is required in the state of Madhya Pradesh due to significant enhancement in irrigated area, availability of quality electricity, cropping intensity, cultivation of remunerative crops and conversion of non agricultural land for agriculture.

It is a matter of great pompous that Department of Soil and Water Engineering, College of Agriculture Engineering, Jabalpur took the initiatives and completed the assignment lucratively. They have prepared district wise water budget of the state of Madhya Pradesh in terms of magnitude, water excess/deficit with percentage. The information compiled in the form of book shall be useful for planning, policy issues, research in agriculture and selection of crops and proper method of irrigation.

I congratulate the authors and wish that this publication will serve the rationale of efficient water management to accomplish the agenda more crop per drop.

Dhirendra Khare
(Director Research Services)

PREFACE

Water is the very source of sustenance of life. Mankind has to constantly remind himself that it is water which makes the planet earth so green so full of life, so different from other plants. All have to see to it that this wealth of the planet should be used judiciously for the best development of human being in a sustainable manner.

This typical resource is scare and even becoming more scares as the time passes. Actually, water is a Techno-Socio-Economical goods, so related to all and all activities. Industries, agriculture, domestic needs all are water dependent. Among these agriculture/irrigation has largest share about 70%. Agriculture sector is now facing an amazing challenge that feeding to increasing number of human being with decreasing water resources. Besides this sector, other sectors are also have increasing demands and giving a great competition. Thus, irrigation is the single activity which needs largest quantity of water in adequate and at the appropriate time to feed explosive/giant population.

These all facts necessitate to have an account of each and every drop of water, about its coming and use at global, national and state level. This process is same as monetary budget of each rupee and known as water budgeting. Water budgeting is useful in policy decision of taking decision regarding crop selection, its management and enhancing water productivity and ultimately farmer income.

Water is in a circulatory movement called hydrologic cycle and not uniformly distributed in time and space. This variation forces for separate planning for different regions.

India has average annual precipitations of 400 Mham and 7 Mham goes as surface flow and only 69 Mham can be utilized. Similarly country has utilizable ground water as 45.2 Mham. Thus, a total of 114 Mham of water is available.

Madhya Pradesh a geographical area of 3,08,245 sq km and constitutes 9.37% of the total area of the country with a great variability. It has 28.2% forest, 78.05% cropped area and 2.6% fallow land. The state is divided into 51 districts and based on various conditions these districts are grouped into eleven agro climatic zones. State has average rainfall of 917 mm and varies from 800-2200 mm.

Madhya Pradesh is rich in is ground water resource and stage of g.w. development varies as low as <5% to more than 100%.Out of 313 blocks of the sate, 24 blocks are over exploited. Five are critical and 19 are semi critical. Rest of blocks are safe, and annual recharge is 35700 ha. m.

Looking to this large variability of the state, district wise budget of water is the need of time for proper agricultural planning. This work is an attempt to full fill the need. District wise water budget of all 51 districts of the state is prepared as per NCA guidelines and presented in coming pages. This budget contains availability of utilizable water, requirement of various sectors and water excess/deficit.

It is a matter of pleasure that there are 36 districts in the state which are having surplus water, which guarantees a secured agriculture. On the other side, in general eastern half of the state does not have excess water while western half has deficit water. Mandsour, Rajgarh, Ujjain, Shajapur and Dhar are the districts of most water deficit having 67954 – 140612 ham lesser water then the requirement. “How much excess/deficit” is a common/frequent question arises in mind. In order to answer this, percentage excess / deficit is also incorporated in this publication. Water is utilized on agricultural area so depth of excess water per unit area is computed and placed here for future planning. It is found that eastern part has a depth available more than 53 cm/ha, central part has a depth available between 19-52 cm/ha while most of the western part and northern part has negative value for water availability for further development.

Thus, a clear scenario of water resource is being presented in different chapter of this document, to care each drop of water in the hands.

Unawareness/ Improper knowledge regarding occurrence, present status and future availability of water seems to be the root cause of non-judicial utilization of water. If his darkness is removed, violence to water may be stopped. With this aim the document is in the hands of user and planners and the authors express their feeling for the state into voice of Atharveda.

शं न आपों धन्वन्याः शमु सन्तनुष्याः। शं न खनित्रिमा

आपः शमु या कुम्भ आमृताः। शिवा न सन्तुवर्षिकोः

अर्थात हमारे लिए निर्जल (मरूक्षेत्र) देश के जल सुखदायी हों। हमारे लिए खोदकर (कूप, नलकूप आदि से) निकाले गये जल सुखदायक हो जलाशयों, तालाबों आदि में भण्डारित जल सुखदायक हों, वर्षा का जल हमको सुखदायक हों। अर्थात् इन स्त्रोतों से उपलब्ध जल को अनेकानेक विधि द्वारा अपने अपयोग में लायें।

Authors

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World Water Balance

Every year 5,20,000 cu km of precipitation falls over the Earth of which 22.4 percent falls on land surface. Out of this land share of 1,16,500 cu km, about 39.4 percent returned back to the ocean through streams and rivers. The water needs of human on the earth are less than eight percent (9100 cu km) of total land share (NASA). In fact total water available on Earth crust is 13,84,120 thousand cu m but most of it i.e. 97.16 percent is beyond the reach of mankind as it stored in ocean and seas. Remaining 2.6 percent fresh water is also not available for utilization as most of it placed in ice and glaciers. Only a small fraction of fresh water is available as surface water. Ground water which can be tapped economically is 9.86 percent (upto 800 m deep) (Baugartuer and Richard, 1975). A brief water balance of six sub-continents is presented in Table 1.

Table 1 Water balance of sub continents (cu km)

Continents	Precipitation	Evaporation	Runoff
Africa	22300	17840	4460
Asia	32200	17710	14490
Australia	7080	4602	2478
Europe	8290	5388	2902
N. America	18300	10065	8235
S. America	28400	16188	12212
Total	116570	71793	44777

Surface water accounting of world's major river basin is presented in Table 2. The runoff potential of major river basins is presented in Table 3.

Table 2 Length, drainage area and average discharge rate of major rivers

River	Length (km)	Drainage area (km^2)	Average discharge (m^3/s)
Amazon	7,062	6,915,000	219,000
Congo	4,371	3,680,000	41,800
Meghna- Ganges-Brahmaputra	2,948	1,635,000	39,320
Orinoco	2,140	880,000	33,000
Yangtze (Chang Jiang)	6,380	1,800,000	31,900
Rio Negro	2,230	691,000	29,300
Parana (Rio de la Plata)	3,998	3,100,000	25,700
Yenisei – Angara-Selenga	5,550	2,580,000	19,600
Lena	4,260	2,490,000	17,100
Madeira – Mamore	3,239	850,000	17,000

River	Length (km)	Drainage area (km^2)	Average discharge (m^3/s)
Mississippi – Missouri	6,270	2,980,000	16,200
Mekong	4,023	810,000	16,000
Pearl – Xi Jiang (West) (Si Kang)	2,200	437,000	13,600
Tocantins	2,699	1,400,000	13,598
Ayeyarwady	2,170	411,000	13,000
Ob'-Irtysh	5,410	2,990,000	12,800
Amur (Heilong)	4,352	1,855,000	11,400
Caroni	952	95,000	10,850
Mackenzie- Peace-Finlay	4,241	1,790,000	10,300
Saint Lawrence- Great lakes	3,058	1,030,000	10,100
Niger	4,167	2,090,000	9,570
Volga	3,692	1,380,000	8,060
Sepik	1,126	80,321	8,000
Columbia	2,000	668,000	7,500
Danube	2,860	817,000	7130
Indus	3,200	1,165,000	6,600
Pechora	1,809	289,532	3,949
Fraser River	1,375	220,000	3,475
Northern Dvina River	744	357,052	3,332
Nile River	6,650	3,400,000	2,830
Rhine	1,320	170,002	2,290
Salween	2,815	320,000	1,614
Po	652	74,000	1,540
Douro	927	97,682	714
Okavango River	1,600	530,000	475
Tagus	1087	80,600	444
Ebro	910	80,093	426
Minho	300	17,081	380
Sebour River	458	40,000	137
River Severn	354	11,420	107
Gaudiana	829	66,800	85
River Thames	346	12,935	65.8
Ganges	2525	1,08,000	12,020

Table 3 Major river basins and their areal extent

Basin	Basin area$(km)^2$
Atlantic Ocean	69,800,000
Arctic Ocean	23,100,000
Pacific Ocean	20,300,000
Indian Ocean	19,400,000
Southern Ocean	14,000,000

UNESCO estimated area of fresh water as 148.8 M km^2 with volume of 35.0 Mkm^3 which is 2.5 percent of total water. The break-up of fresh water is also given as the percentage of fresh ground water, soil moisture, polar ice, other ice and snow, fresh water lakes, marshes, rivers, biological water and atmospheric water, respectively as 30.1%, 0.05%, 68.6%, 1.0%, 0.26%, 0.03%, 0.006%, 0.003% and 0.04%.

Water balance of India

India is a vast country with greater degree of climatic variability. It has ice ladden mountains in the north to three fourth peninsular land. All types of climate from arid climate of Rajasthan to hot- humid climate of Tamilnadu exists in India. The rainfall varies from less than 200 mm to more than 10000 mm. The rainfall map of India is shown in Fig. A

When rain occurs over the land a part of it intercepted by the vegetation and the remaining amount reaches to ground surface which will either enters into it or flows over the surface. The infiltrated water may either reach to ground water table or further comes over to surface as effluent stream. Vegetation is the major user of water apart from direct evaporation to atmosphere. An estimate of water balance of India is presented in Table 4. Total volume of precipitation over surface is 3838 – 4000 cu km out of which 48.8 – 50.1 percent goes back to ocean as stream flow. The ground water accreditation has share of 10.8 to 11.3 percent while ET occurs in the tune of 1452-1614 cu. km.

Table 4 Annual water balance for India

Component	Water volume cu. km.	Precipitation (%)
Precipitation	3838-4000	100
Stream flow	1953	50.1 – 48.8
GW	433	11.3 – 10.8
ET	3838 – (1953+433) = 1452	37.8
	4000 – (1953+433) = 1614	40.3

The runoff draws through various basins. A comprehensive water balance of major basins is presented in Table 5. Out of seven major basin of India, the Ganga basin has the largest area. Though magnitude of rainfall is only second last among basins, it still contributes maximum (905.4 BCM) in the input basket of the India. The Ganga flows in such a terrain it contributes maximum in ground water bank. Unlike Brahmaputra basin all other basins have lesser stream flow than the gain from precipitation.

Table 5 Water balance for select basins

Component	Narmada	Godavari	Cauvery	Krishna	Ganga	Indus	Brahmaputra
Area, sq km	98396	312812	81155	258948	861452	321289	194413
Precipitation, mm	1109	1107	1032	838	1051	1097	2589
Precipitation. (BCM)	109.6	346.3	83.8	217	905.4	352.5	503.4
Stream flow (BCM)	45.64	110.54	21.36	69.81	525.4	73.31	629.05

Component	Narmada	Godavari	Cauvery	Krishna	Ganga	Indus	Brahmaputra
Ground Water (BCM)	10.83	40.65	12.30	26.41	171	26.49	26.55
ET (BCM)	53.13	195.11	50.14	120.8	209.4	252.7	152.2
ET %	48.5	56.3	54.8	55.65	23.1	71.7	-

Utilizable surface water resources of major river basins are shown in Table 6. The table shows total water resources potential on an average during a year is 1869 BCM and utilizable surface water is 690 BCM. The proportion of utilizable surface water resources to water resources potential is very high in smaller basins except in Mahi and West flowing River Basins between Tapi and Tadri. In Pennar and some of the East flowing river basins between Pennar and Kanyakumari, the total surface utilization water exceeds annual availability of natural flows. The proportion of utilizable surface water to average water resources potential is found minimum in Brahmputra sub-basin.

Table 6: Surface Water Resources in different River Basins

Sl. No.	River Basin	Catchment Area (Sq. Km.)	Average Water Resources Potential (BCM)	Utilizable Surface Water Resources (BCM)
1	Indus (up to border)	321289	73.31	46.0
2	Ganga – Brahmputra - Meghna			
	a) Ganga	861452	525.02	250.0
	b) Brahmputra	194413	537.24	24.0
	c) Barak & Others	41723	48.36	
3	Godavari	312812	110.54	76.3
4	Krishna	258948	78.12	58.0
5	Cauvery	81155	21.36	19.0
6	Subernarekha*	29196	12.37	6.8
7	Brahamani & Baitarni	51822	28.48	18.3
8	Mahanadi	141589	66.88	50.0
9	Pennar	55213	6.32	6.9
10	Mahi	34842	11.02	3.1
11	Sabarmati	21674	3.81	1.9
12	Narmada	98796	45.64	34.5
13	Tapi	65145	14.88	14.5
14	West flowing rivers from Tapi to Tadri	55940	87.41	11.9
15	West flowing rivers from Tadri to Kanyakumari	56177	113.53	24.3
16	East flowing rivers between Mahanadi & Pennar	86643	22.52	13.1
17	East flowing rivers between Pennar & Kanyakumari	100139	16.46	16.5
18	West flowing rivers Kutch and Saurashtra including	321851	15.10	15.0

Sl. No.	River Basin	Catchment Area (Sq. Km.)	Average Water Resources Potential (BCM)	Utilizable Surface Water Resources (BCM)
	Luni			
19	Area of inland drainage in Rajasthan	-	Negl.	-
20	Minor river draining into Myanmar (Burma) & Bangladesh	36302	31.00	-
	Total		1869.37	690.1
Source: B.P. Directorate, CWC.				
S: Reassessment of water resources potential of India March 1993 and December 1999, CWC.				
#: Report of the Standing Sub-Committee for assessment of availability and requirement of water for diverse uses in the country, August 2000.				
Note:* :Combining Subernarekha and other small rivers between Subernarekha and Batarni				

Ganga – Brahmputra – Meghna system is the major contributor to total water resources potential of the country. Its share is 59% in total water resources potential of the various rivers (Table 7). Due to various constraints of topography, uneven distribution of resource over space and time, it has been estimated that only about 1123 BCM of total potential of 1869 BCM can be put to beneficial use, 690 BCM being due to surface water resources.

Table 7: Percentage of Water Resources Potential in Major basins

River Basin	Water resources Potential	Utilizable surface Water
	(% of total 1869 BCM)	(% of total 690 BCM)
Ganga – Brahmputra – Meghna	59.4	39.7
Indus (up to border)	3.9	6.7
Godavari	5.9	11.1
Krishna	4.2	8.4
Mahanadi	3.6	7.2
Narmada	2.4	5.0
Others	20.6	21.9

Total annual replenishable ground water potential of the country has been estimated as 433 BCM (Table 8).It shows 14 states comprise more than 90% of ground water potential.

Table 8: Annual Replenishable Ground Water Resources in India

State	Annual Replenishable Ground Water Resources (BCM/Year)	Percentage of Total
Andhra Pradesh	35.89	8.29
Assam	28.52	6.59
Bihar	29.34	6.78
Chhatisgarh	12.42	2.87
Gujarat	18.57	4.29
Karnataka	17.03	3.94
Madhya Pradesh	35.04	8.10
Maharashtra	33.95	7.85
Orissa	17.78	4.11
Punjab	22.53	5.21
Rajasthan	11.94	2.76
Tamil Nadu	21.53	4.98
Uttar Pradesh	77.19	17.84
West Bengal	29.25	6.76
Others	41.74	9.65
Total	432.72	100.0
Sources: Central Ground Water Board, Min. of Water Resources		

Water resources of India

The National Commission on Agriculture in 1976 estimated water resources in the country for 1974 and also projected for 2000 and 2025 based on certain empirical formulae and assumptions related to runoff characteristics of soil, rainfall events and vegetation cover. In this document, an attempt has been made to intropolate figures for 2017 from the projections of 2000 and 2025. India is a vast country with a geographical area of 328 Mha. The average annual rainfall of India is estimated at 1194 mm. Taking factors like average rainfall, soil characteristics and vegetation types into consideration, it has been estimated that out of the average annual precipitation of 400 Mha-m, about 70 Mha-m is lost to atmosphere. Of the remaining 330 Mha-m, about 115 Mha-m flows as surface runoff and the rest 215 Mha-m soaks into the ground. In the absence of comprehensive observations and availability of reliable data, the figures in the water budgeting are only indicative rather than accurate values (NCA, 1976).

Surface flows

The surface water flows consists direct runoff from rainfall, snowmelt and flows in streams regenerated from groundwater. The Irrigation Commission (1972) has placed the total annual surface water flows in the country at 180, 183 and 185 Mha-m for the years 1974, 2000 and 2025, respectively. This was based largely on statistical analysis of the flow data wherever available and on suitable rainfall- runoff relationships for areas where such data were meager. This amount includes 20 Mha-m brought into the country in the form of streams and rivers from catchments lying outside the country. About 45 Mha-m pertain to regenerated flow from groundwater as assessed from river flows during non-rainy season. The remaining 115 Mha-m constitute direct contribution by precipitation of which about 10 Mha-m is in the form of snowfall. Total water surface flow works out to be 184.6 Mha-m at present, of

which, about 24.2 Mha-m is stored in various reservoirs and tanks. Out of which 20 percent is lost through evaporation loss is estimated at 8.8 Mha-m and is expected to increase to 10 Mha-m by 2025 AD. Similarly the storage would be about 25 Mha-m due to future construction of projects. Of the 154 Mha-m of water that flows in the rivers annually at present, the utilization through diversion works and direct pumping aggregates to 40.6 Mha-m which is more that of utilization from storage works. The remaining water goes to the sea or adjoining countries. On full development, the water through diversion works or direct pumping is expected to increase to 45 Mha-m and the remaining 105 Mha-m would continue to flow to the sea and outside the country in 2025 AD.

Groundwater

With the addition of 10 Mha-m from streams and 25 Mha-m from irrigation systems to the 50 Mha-m from precipitation and on development of all the resources ground water resources are likely to increase to 85 Mha-m by 2025 AD. A portion of this evaporates though capillary action or is drawn from plants for transpiration in areas where the water table is high, a portion is extracted though wells, tube wells, etc. for irrigation and other purposes and a large portion is returned to the surface as regenerated flows in rivers. Any portion that is not disposed in the above manner makes an addition to groundwater.

Transpiration

Transpiration takes place from irrigated crops, dry land crops and forests and other vegetation. Based on prevailing temperature, humidity and cropped area, the ET losses could be estimated. As projected by NCA, the current ET put together from forests, irrigated crops and dry land crops is estimated at 122.2 Mha-m. With development of irrigation, the irrigated area will increase and there will be corresponding reduction in rainfed area with overall increase in gross area sown. At the same time, there will be no significant change in the forest area in future. On full development of irrigation, the ET requirement will increase to 125 Mha-m by 2025 AD. But it is interesting to note that the rain water stored in soil is mostly used by dry land crops and to some extent by irrigated crops when raised during monsoon.

Evaporation

In the hydrological cycle, evaporation is a major item without which water does not circulate in the atmosphere. It has been estimated that about 70 Mha-m (17.5%) of total precipitation goes back to the atmosphere from soil immediately. Besides the evaporation from soil moisture and ground water decreases on account of increase in transpiration due to expanding gross sown area and unscientific ground water exploitation. On the other hand, the evaporation from reservoirs does increase with expansion of irrigation projects. Assuming that there would be no significant change in precipitation in the near future, the evaporation from it would remain more or less same.

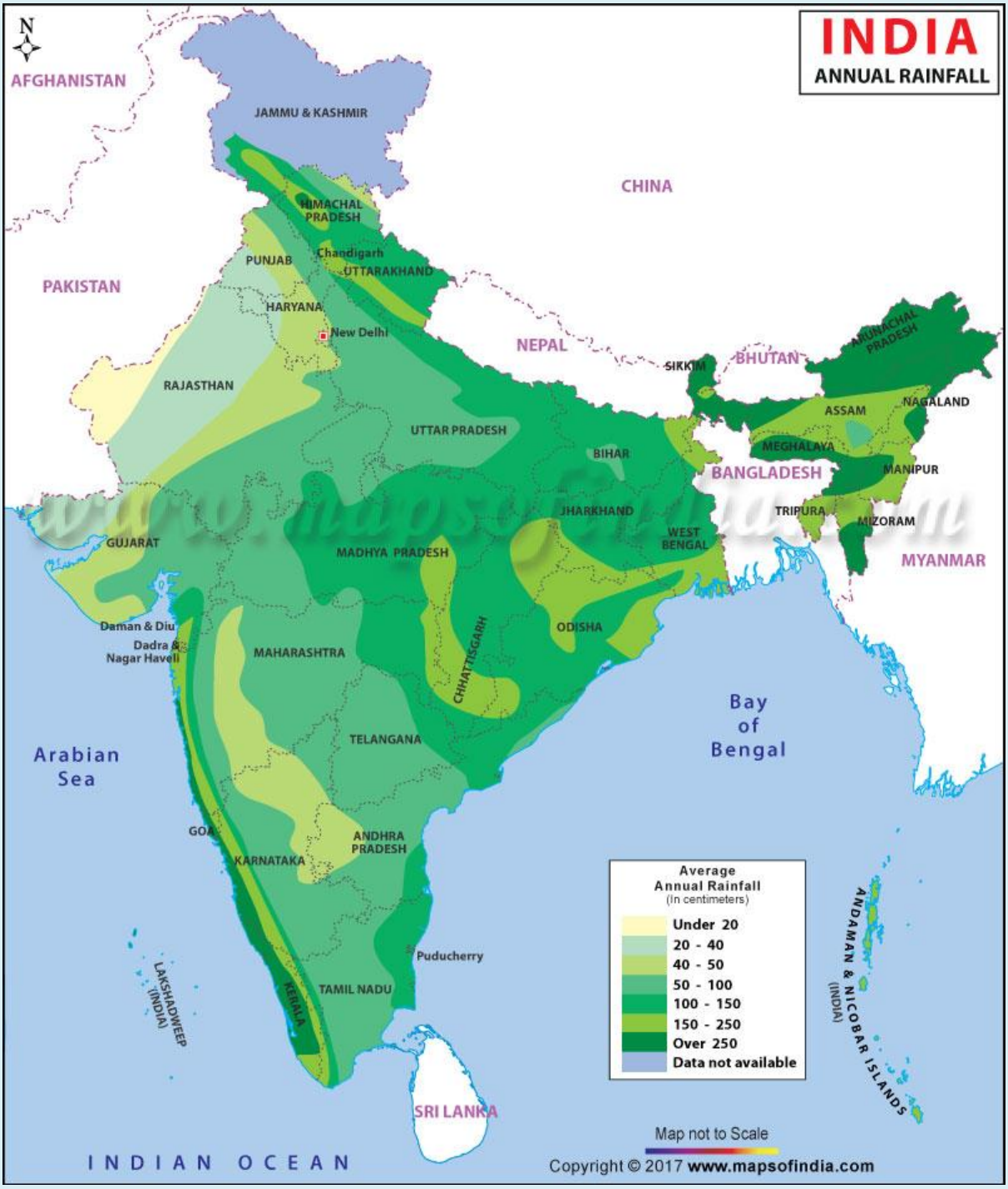


Fig A. Rainfall map of India

Source: mapsofindia.co

Water Budgeting of Madhya Pradesh

Madhya Pradesh is situated in the centre of the nation having geographical area of 308245 sq. km. It has 28.2% of its land under forest, 78.05% total cropped area, 50.0% net sown area and 2.6% fallow land. The state comprises of 51 districts which are regrouped into eleven Agro climatic zones namely, Chhattisgarh Plains, Northern Hill Region of Chhattisgarh, Central Narmada Valley, Vindhya Plateau, Gird Region, Bundelkhand, Satpura Plateau, Malwa Plateau, Nimar Plains and Jhabua Hill Region.

District wise average annual rainfall is presented in Fig. 1. Districts are arranged in descending order of magnitude to clear the variability of rainfall. It has average rainfall of 917 mm. High rainfall in the range of 1100 mm to 2200 mm occurs in Seoni, Balaghat, Umaria, Katni, Sidhi, Panna and Satna. Low rainfall below 800 mm occurs in Ratlam, Ujjain, Barwani, Khargone and Rajgarh district.

Dynamic ground water scenario of MP

Stage of Groundwater development – State of ground water development is presented in Fig.2. It is clear from the graph that the ground water development varies from more than 100% to less than 5% (Fig. 2). This divide the state into over exploited to safe blocks. MP has 313 blocks and its division according stage of development is given in Fig. 3, there are 24 blocks comes under over exploited category, five in critical category and 19 are under semi critical category. Rests of blocks of the state are under safe category. An accounting of ground water is presented in Fig.4 depicting ground water availability after 25 years. About 40% ground water is yet to be utilized for future irrigation development. The annual ground water recharge depends on recharge worthy area of the state. Madhya Pradesh has 38913 km^2 under hills which restricts annual recharge to 35700 ha m (Fig. 5).

Water Budget of Madhya Pradesh in brief:-

National Commission on Agriculture has given a procedure to compare water budget of a state based on rainfall and water demand by various sectors like crop water management, domestic, livestock demand and water demand towards industries.

District wise water budget is prepared and presented in next chapter. Here, the water budget in brief is presented through maps shown in Fig. 6 – Fig. 10.

As per NCA guidelines the major input for the water balance of an area is its normal rainfall and when it multiplied by the geographical area it gives quantum of water generated. After deducting evaporation, surface flow, flow outside of the area and ground water addition and outflow, the water available for utilization in the state is computed and presented in Fig. 6. Figure shows lesser amount of water availability in Western and Northern part of the state, moderate water availability in eastern part and more water availability in central and east-south part of the state. This availability is in terms of magnitude of the area encompasses in a particular district. It also has dimension of the normal rainfall. Obviously, lesser geographical area with lesser rainfall generates lesser amount of water. Out of 51 districts of the state, 6 districts generate 437842 – 635483 ha-m of water, 8 districts generate 340160 – 437841 ha-m of water, 13 districts generate 262973 – 340159 ha-m, other 11 districts generate 167654 – 262972 ha-m and 13 other districts generate 114182 – 167653 ha-m of water. It means, only 14 districts generate more than 50 percent of water of the state.

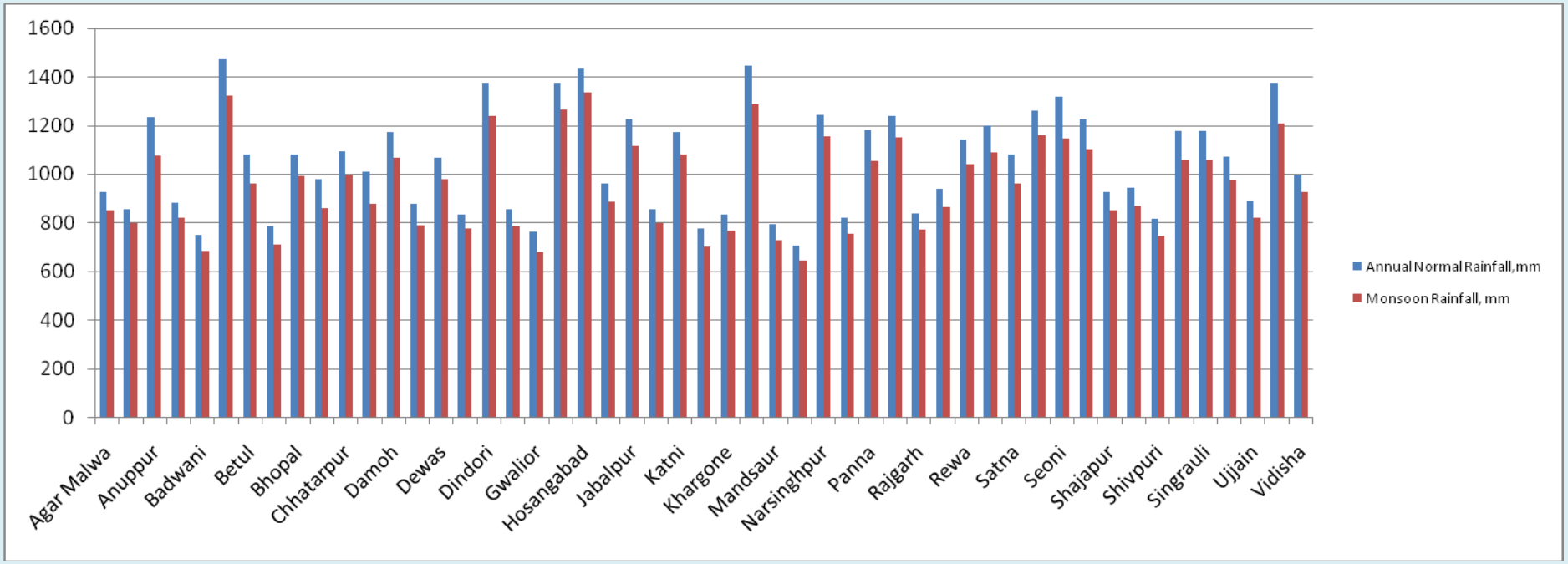


Fig. 1 Annual rainfall and monsoon rainfall of different districts, mm

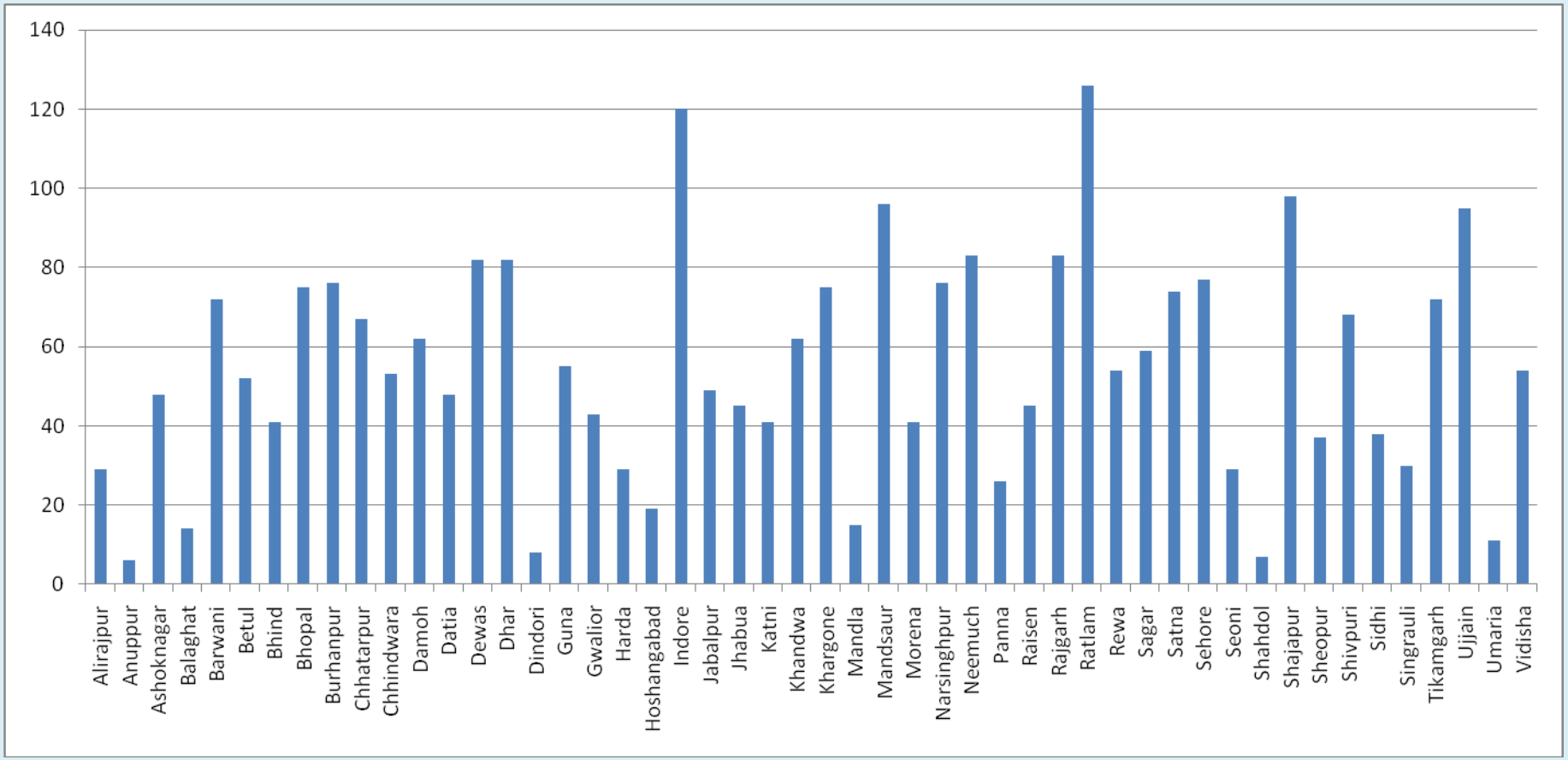


Fig. 2 Stage of ground water development, % in different districts of Madhya Pradesh, Source WRD GoMP

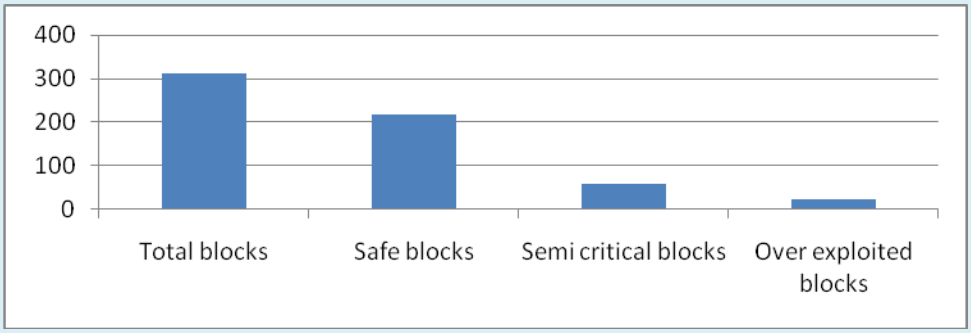


Fig 3 Categories of blocks for ground water utilization, Source WRD GoMP

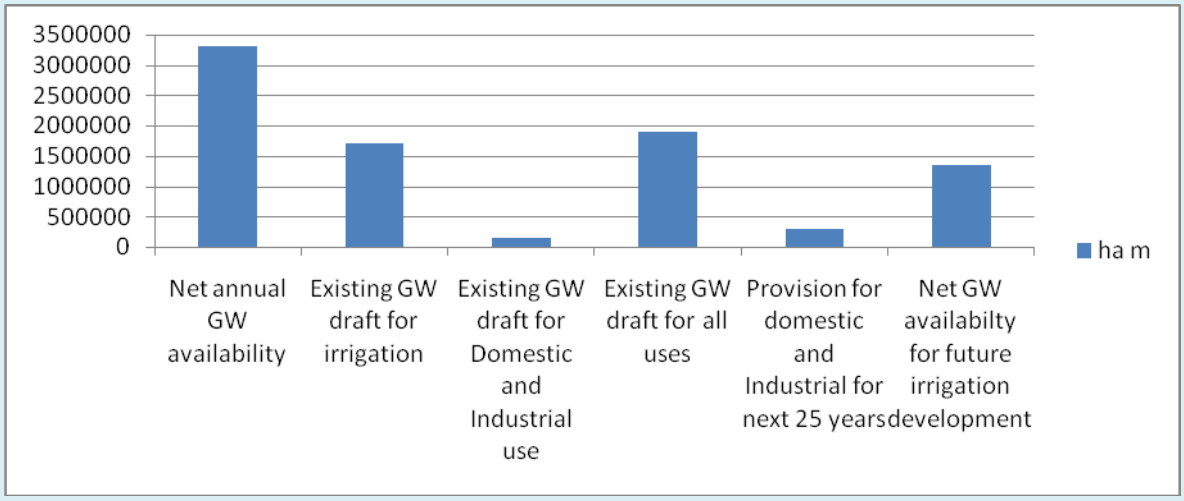


Fig 4 Ground water resources of state, Source WRD GoMP

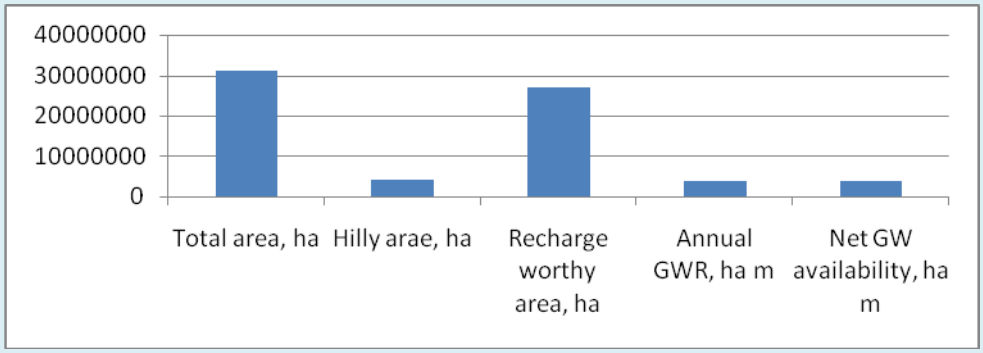


Fig. 5 Total replenishable Ground water resources of state, Source WRD GoMP

District wise water required by different sectors is presented in Fig 7. A look on figure reveals lesser water requirement in eastern part of the state and in 2-3 districts in western part of the state which is sharing its district boundaries with neighboring Gujrat state. Central part and rest of the western part of the state is high water demanding area. The northern part of the state is of moderate water demand area. Out of total 51 districts, 7 districts has maximum water demand of the magnitude 331279 – 384400 ha-m, 6 districts requires 263338 – 331278 ha-m of water to meet out various demands. 20 districts requires water between 192793 – 26337 ha-m, 7 districts demands water 132940 – 192792 ha-m. Only 11 districts

require water below 132939 ha-m. Here 13 districts require about 40 percent of water generated from the state.

Based on water available for utilization and water requirement by different sectors, the water excess/deficit of different districts are calculated and presented in Fig 8. Most of the districts (36) have surplus water which can be used for future expansion of agriculture. In general Eastern half of the state does have excess water while Western half has deficit water. Betul, Chhindwara, Balaghat, Mandla and Seoni have excess water of tune of 199008 – 483693 ha-m i.e. about 60 percent of excess water is with these districts. Mandsaur, Rajgarh, Ujjain, Shajapur and Dhar are the most water deficit districts having 67954 to 140612 ha-m lesser water than the requirement. To make picture clearer the percentage excess/deficit was also computed. This shows how much water is in excess or deficit in comparison to the requirement. it is illustrated in Fig 9. Among water excess districts, Balaghat, Mandla and Umaria belongs to 143 to 333% excess water whereas 15 districts of western and northern part of the state have water deficit of 8 to 37 percent. Interestingly, three districts out of five districts lying in Narmada valley have water excess below 24%.

The amount of water available on per hectare basis is more important for future planning of utilization. Therefore, depth of excess/deficit water per unit area is computed and it is on the basis of net sown area which is presented in Fig 10. Eastern Madhya Pradesh has lesser net sown area in comparison to other region of the state. Due to this, excess water availability in eastern part, more depth (>53cm/ha) is available in this region Fig 11. Whole of the central Madhya Pradesh has water depth between 19-52 cm/ha. Most of western and northern parts have negative values for water availability for further development, it is required to save sufficient amount of water in these districts.

Water requirement of a particular district is computed by adding water required by different sectors. These sectors are agriculture (Fig 12), domestic (Fig 13) and live stock (Fig 14). A study of these figures reveals that the water requirement towards domestic use and for live stock is much lesser than the water required towards crops. Except two districts of western Madhya Pradesh, whole western and almost all districts of central MP requires water more than 186376 ha-m whereas most of the eastern MP does require less than 145055 ha-m towards crops. Domestic water requirement is an indicator of population density also due to which five districts Indore, Bhopal, Sagar, Jabalpur and Rewa requires more than 10981 ha-m water to meet out domestic needs. 12 districts require less than 4164 ha-m of water and rest of districts require between 4164 to 10981 ha-m of water. Animal husbandry population decides the water requirement of any district. 7 districts required more than 7136 ha-m of water which is more than 35% of total water required towards animal husbandry. Datia, Bhopal and Harda have very thin population of animal husbandry and require less than 2666 ha-m of water.

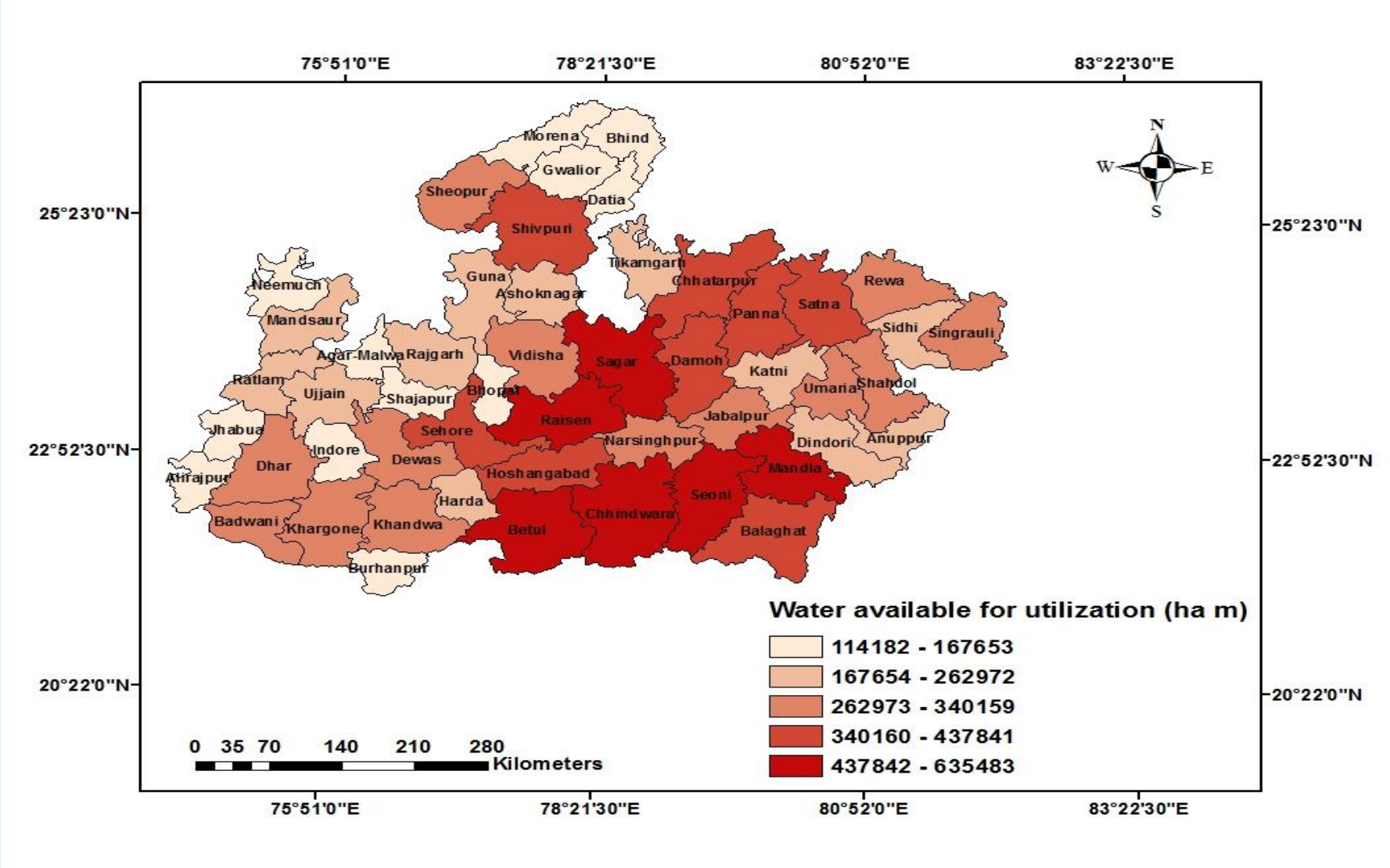


Fig 6 District water availability for utilization, ha m

Agro climatic zone wise water budgeting in brief:-

Madhya Pradesh is divided into 11 agro climatic zones; Chhattisgarh plains, Northern Hills of Chhattisgarh, Kymore plateau & Satpur hills, Central Narmada Valley, Vindhya Plateau, Gird Region, BUndelkhan, Satpura Plateau, Malwa Platea, Nimar Plains and Jhabua Hills. Different components of water budget, based on agro climatic zone, are preared and shown in Fig 15 – Fig 22. Water available for utilization is maximum (2515118 ha-m) in Vindhya Plateau followed by Kymore Plateau. Satpura Hills (2401786 ha-m) and Northern Hill region of Chhattisgarh (1970522 ha-m). Jhabua Hills possess the least amount of water available (263274 ha-m) owing to its lesser geographical area and low rainfall, Fig15. Total water requirement by different sectors is maximum in Malwa Plateau (2364968 ha-m) followed by Vindhya Plateau (2025157 ha-m) and Kymore Plateau & Satpura hills (1427409 ha-m). The least requirement of water comes from Jhabua Hills. Five agro climatic zones ACZ – III, V, VI, IX and X needs water more than 10.00 lakh ha-m while three zones ACZ – I, VIII and XI needs water equal to or less than 5.00 lakh ha-m (Fig16). ACZ III, IV and VIII have more than 5.00 lakh ha-m of surplus water after meeting out its requirement. All ACZ except ACZ IX have surplus water for future development. However, ACZ – VI has marginal (9400 ha-m) water in surplus Fig 17. ACZ I has water more than three times of its requirement (Fig 18) while ACZ IV and VIII has more than double water in excess. Six zones have less than 30% excess water. Malwa is deficit by 24% while Gird region is almost balancing its need and availability.

Per hectare availability of water in terms of depth is also worked out and found that two zones ACZ VI, VII and XI has less than 10 cm/ha for further development. Malwa being deficit by 19 cm/ha while about 100 cm/ha or more water is available in ACZ – I and ACZ II Fig 19.

Sector wise water requirement are given in Fig 20 – Fig 22. Malwa Zone leads in water required by crops, domestic use and towards animal husbandry, which is followed by Vindhya Plateau, Nimar Plain and Kymore Plateau with lesser or more magnitude.

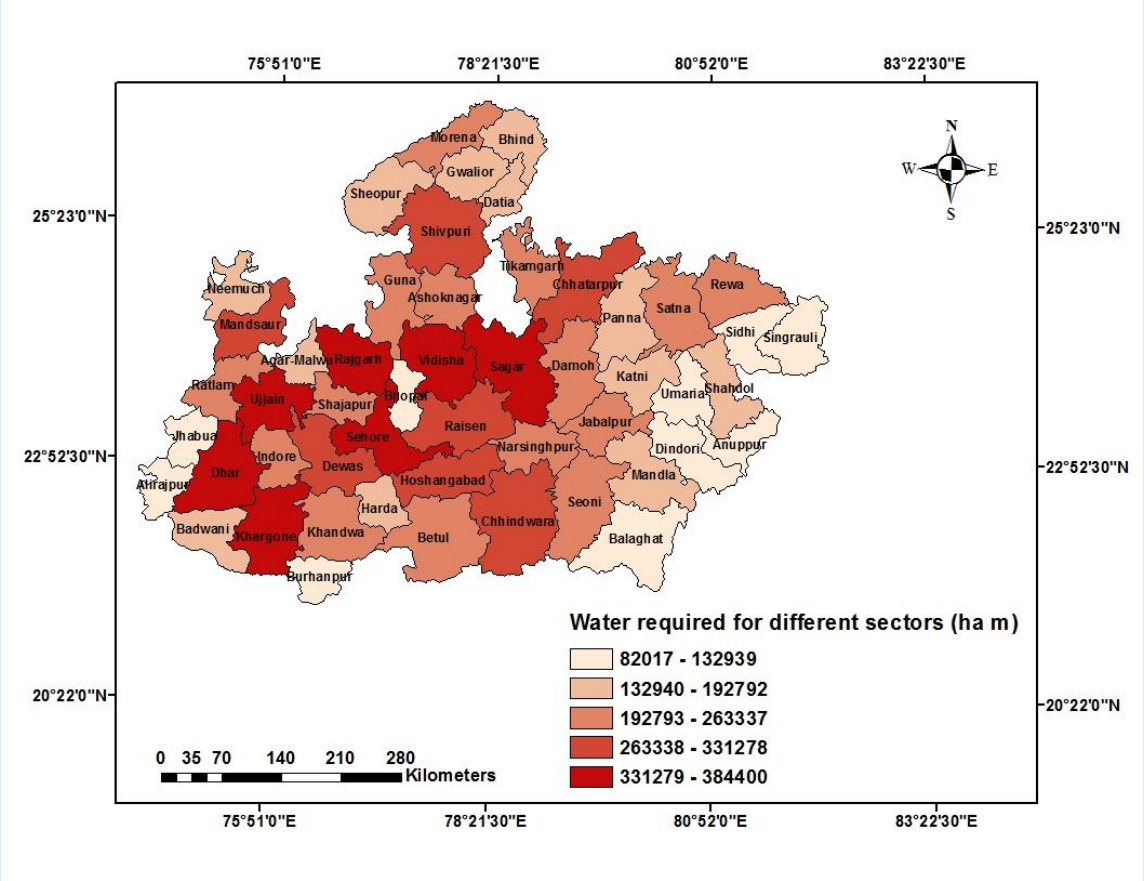


Fig 7 District water requirement by different sectors, ha-m

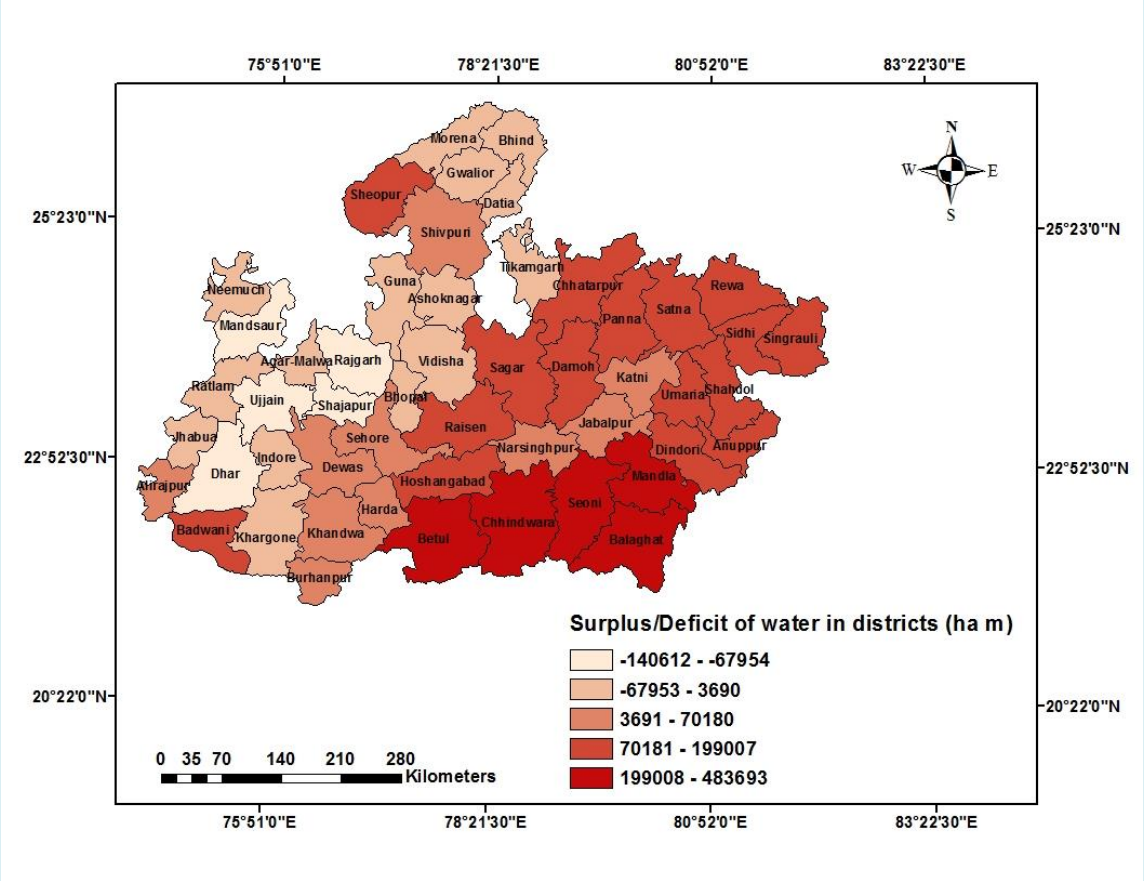


Fig 8 Availability of surplus-deficit water, ha-m

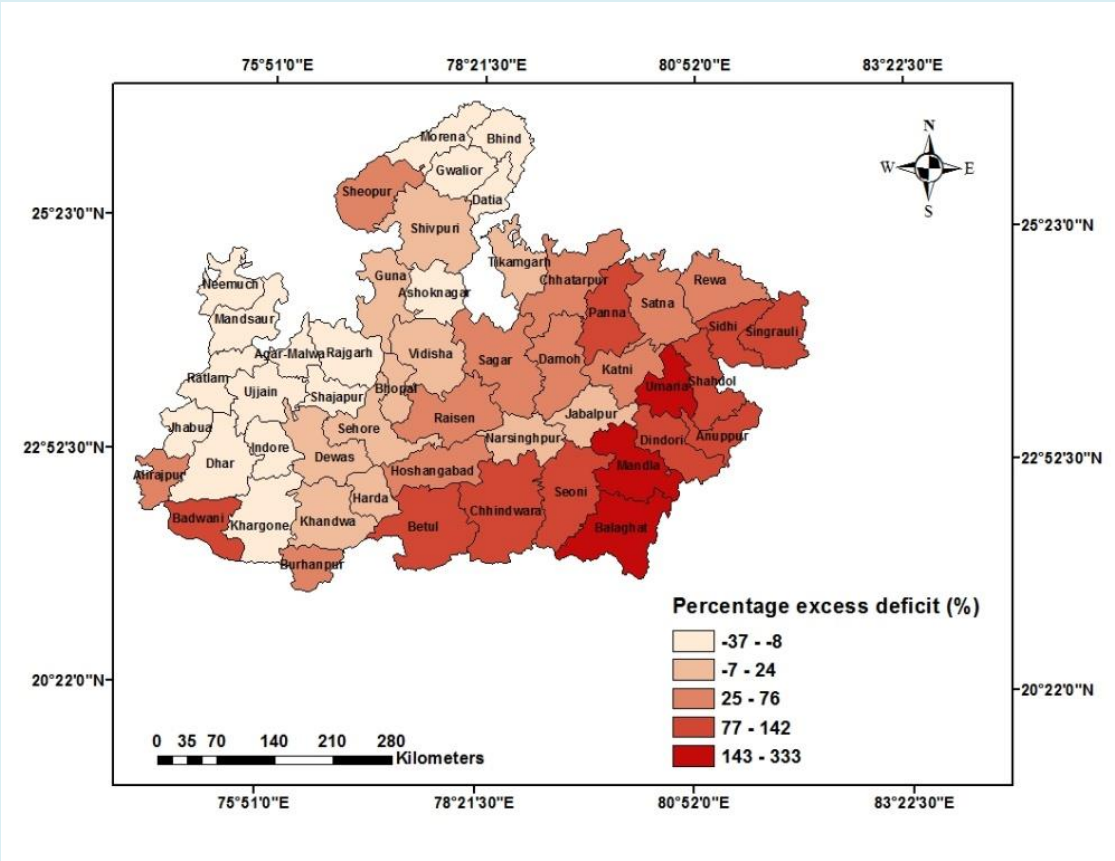


Fig 9 Excess – Deficit water availability in percent

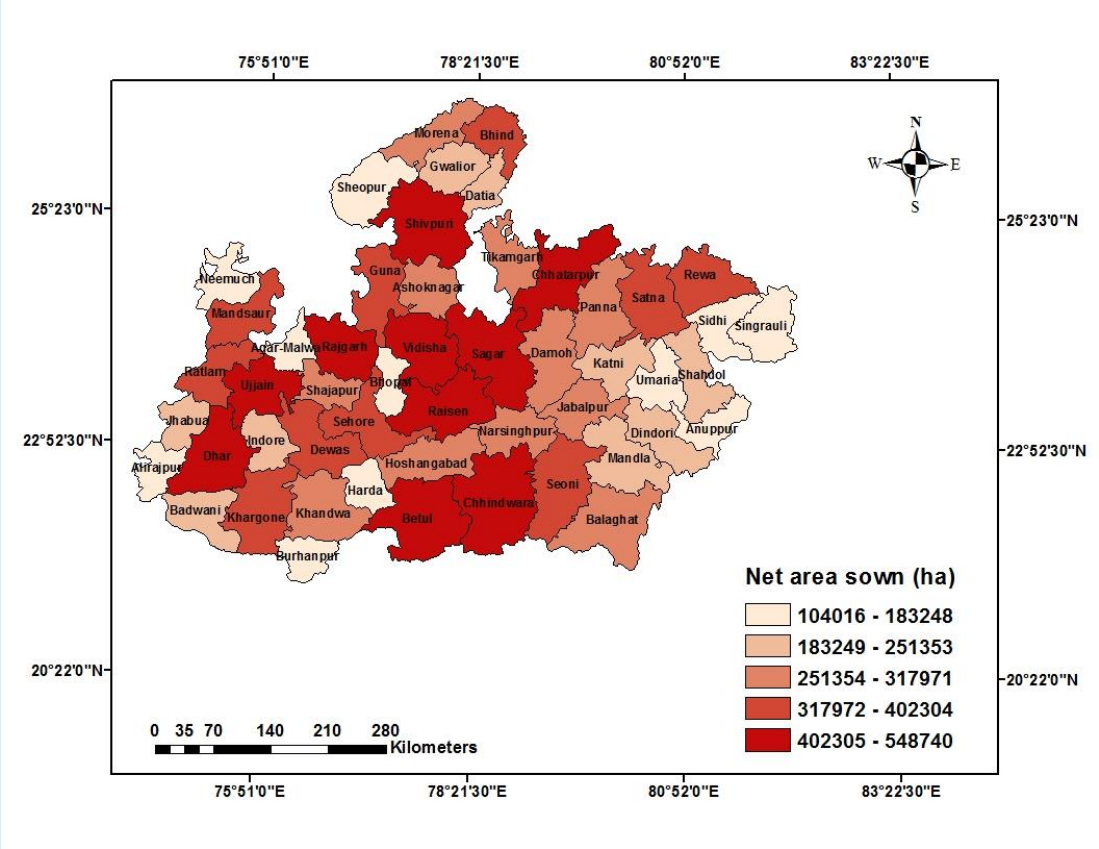


Fig 10 Net area sown in districts, ha-m

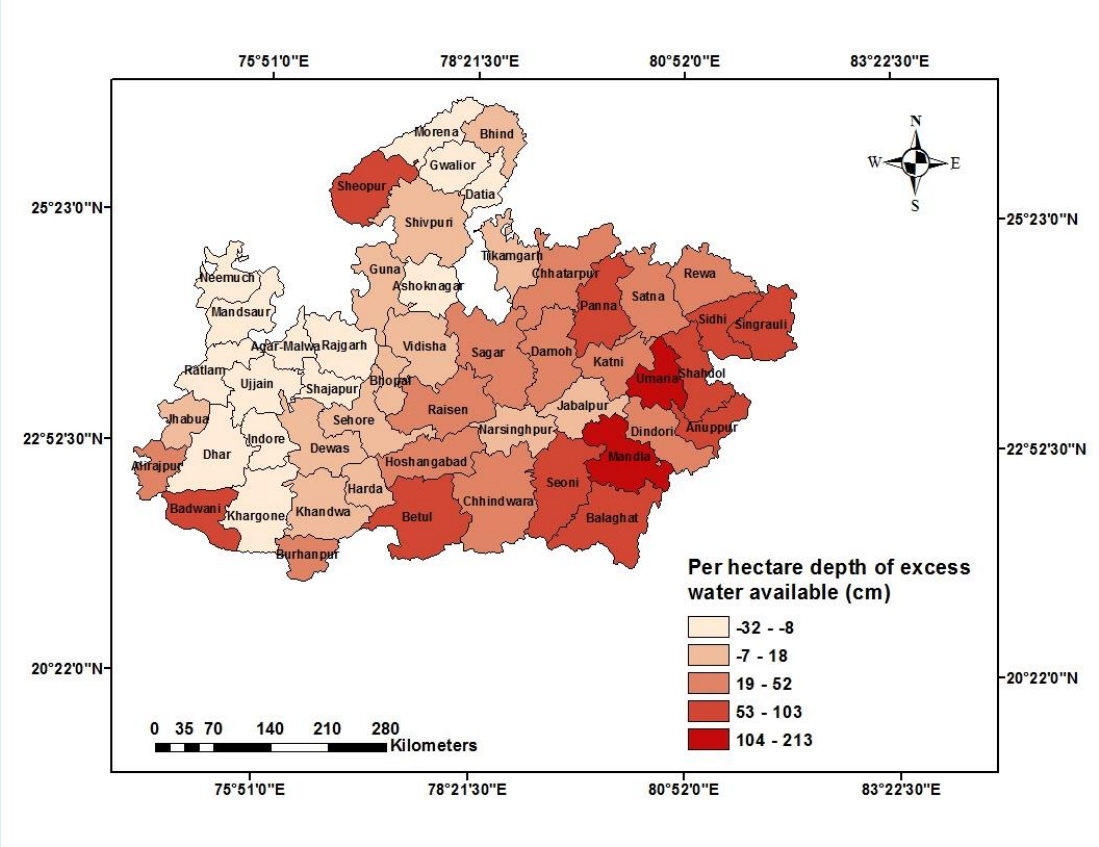


Fig 11 Depth of water available in districts, cm

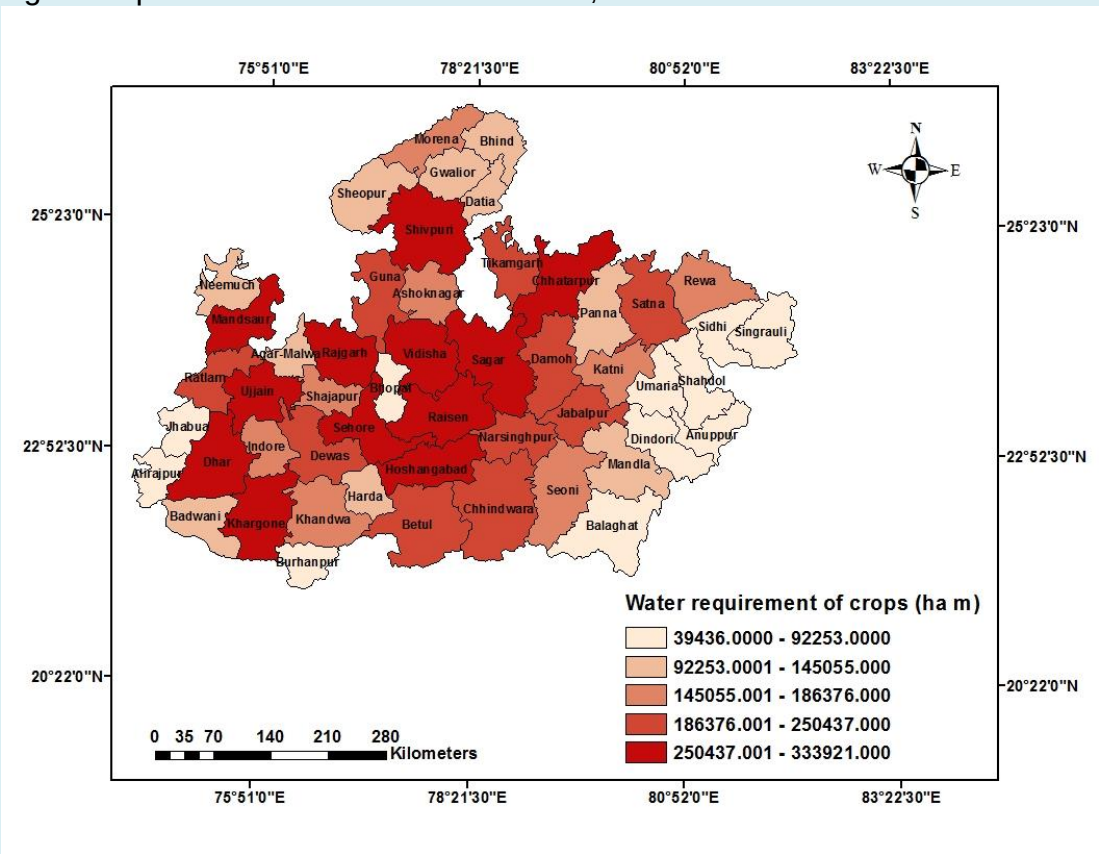


Fig 12 Water demand by crops, ha-m

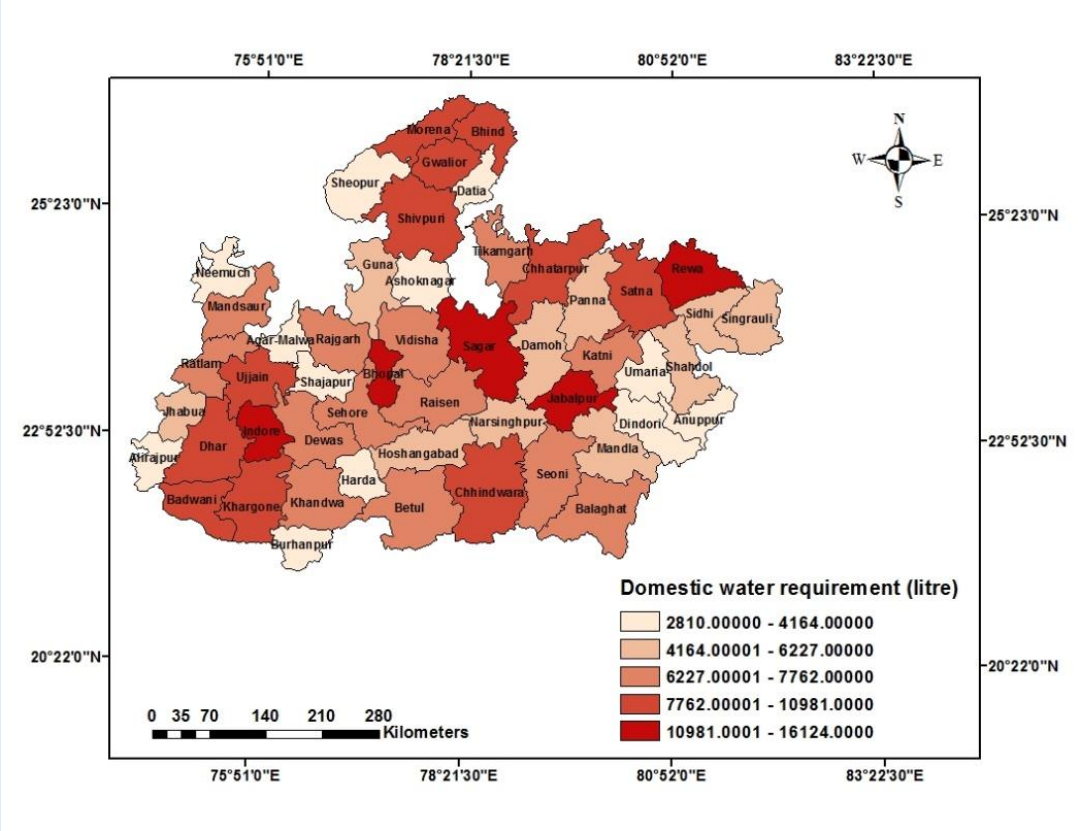


Fig 13 Domestic water demand of districts, ha-m

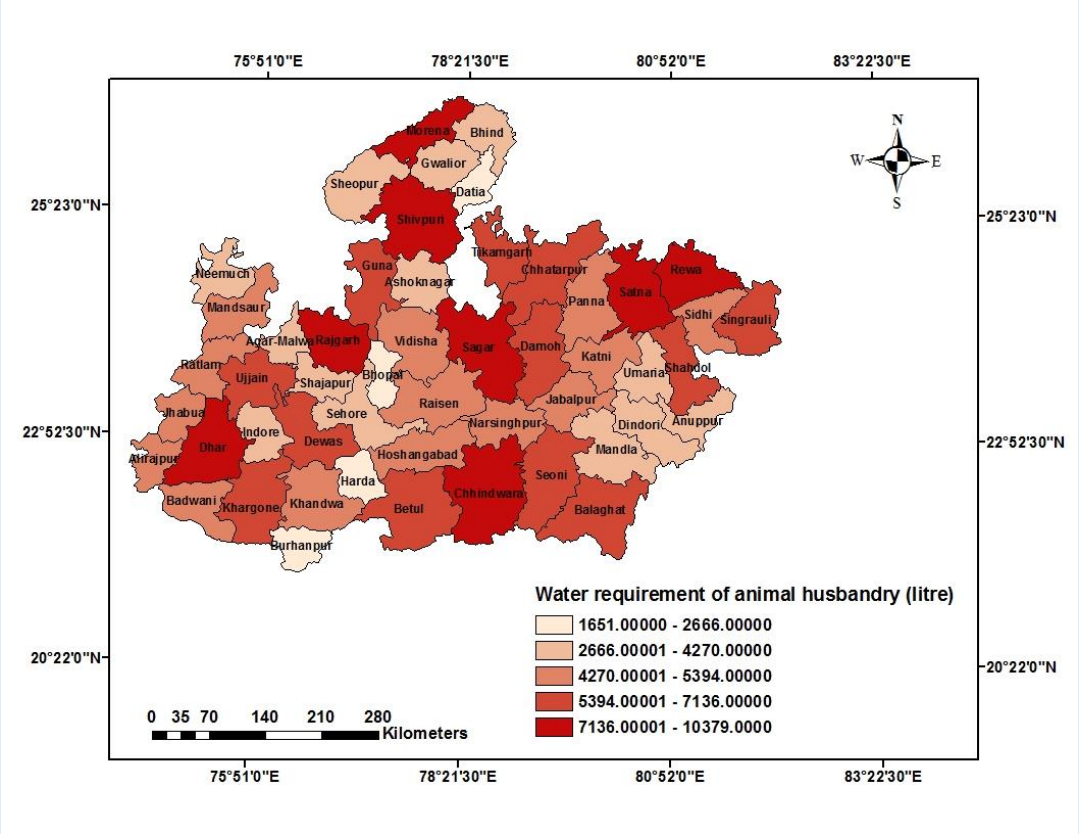


Fig 14 Water needs of livestock in different districts, ha-m

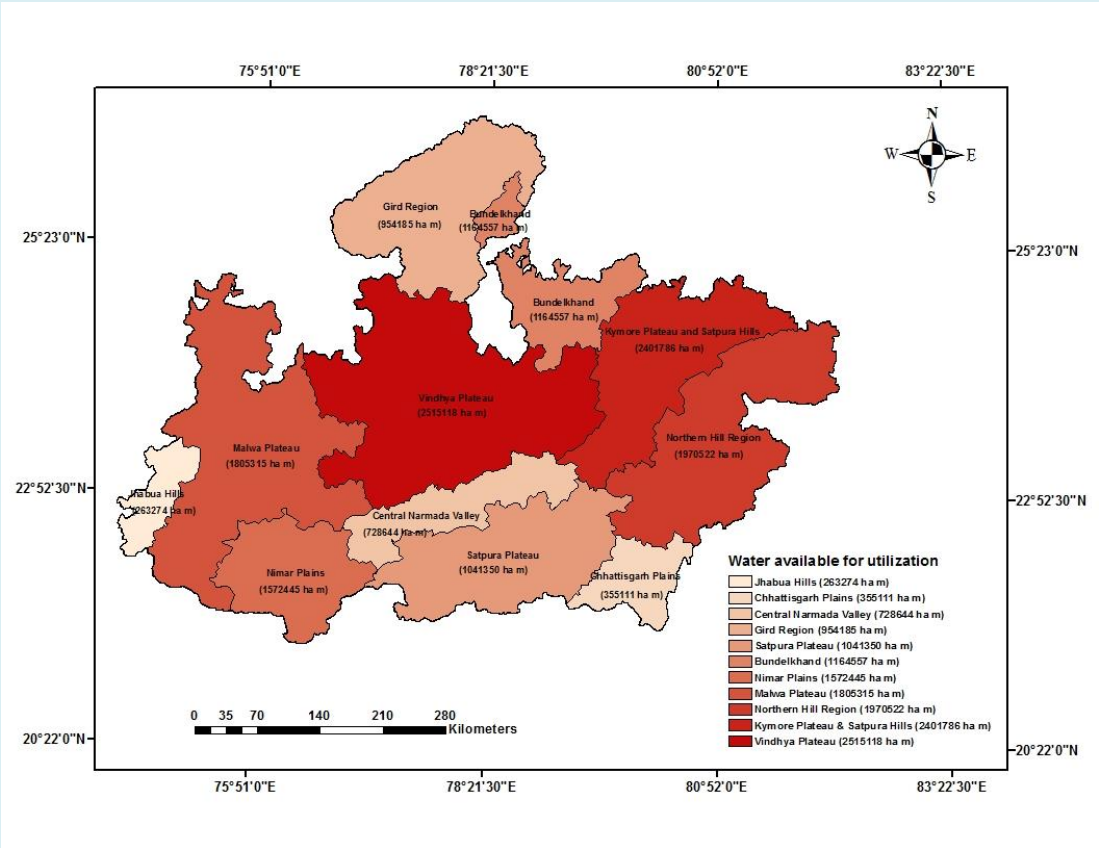


Fig 15 Water availability for utilization in different Agroclimatic zone, ha-m

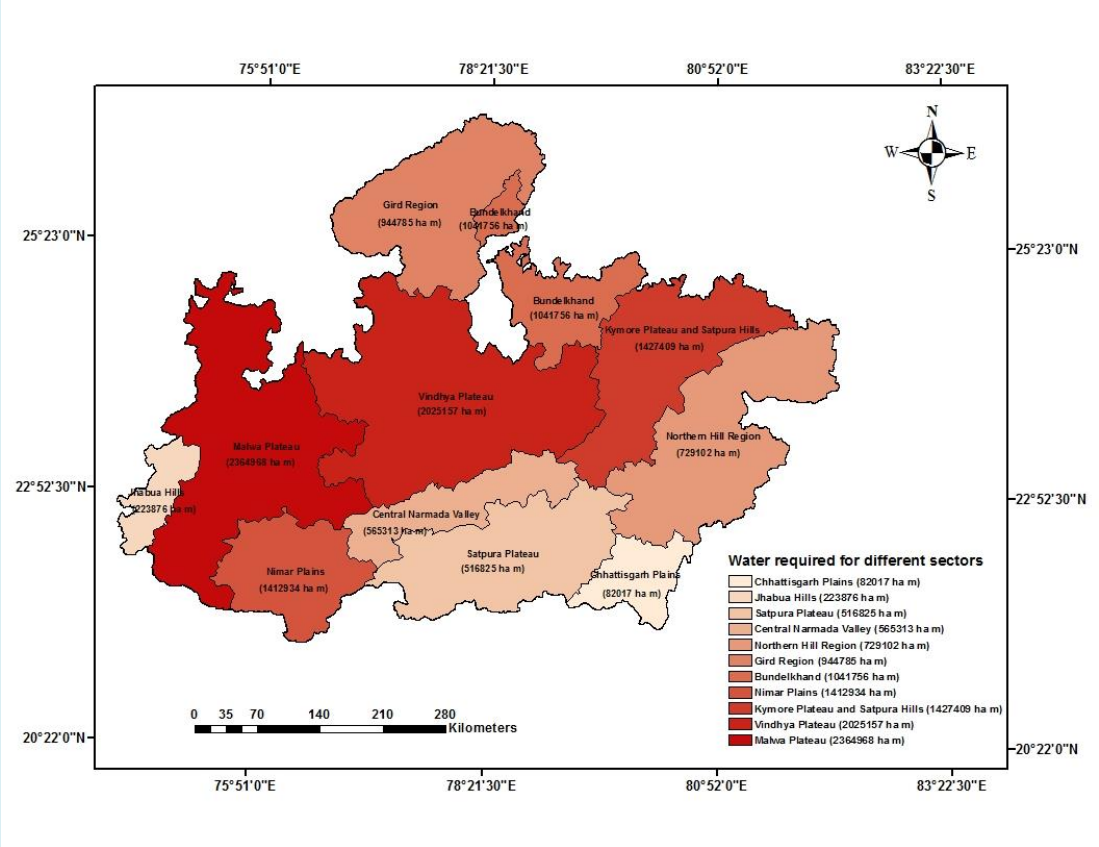


Fig 16 Water requirement in different sectors of Agroclimatic zones, ha-m

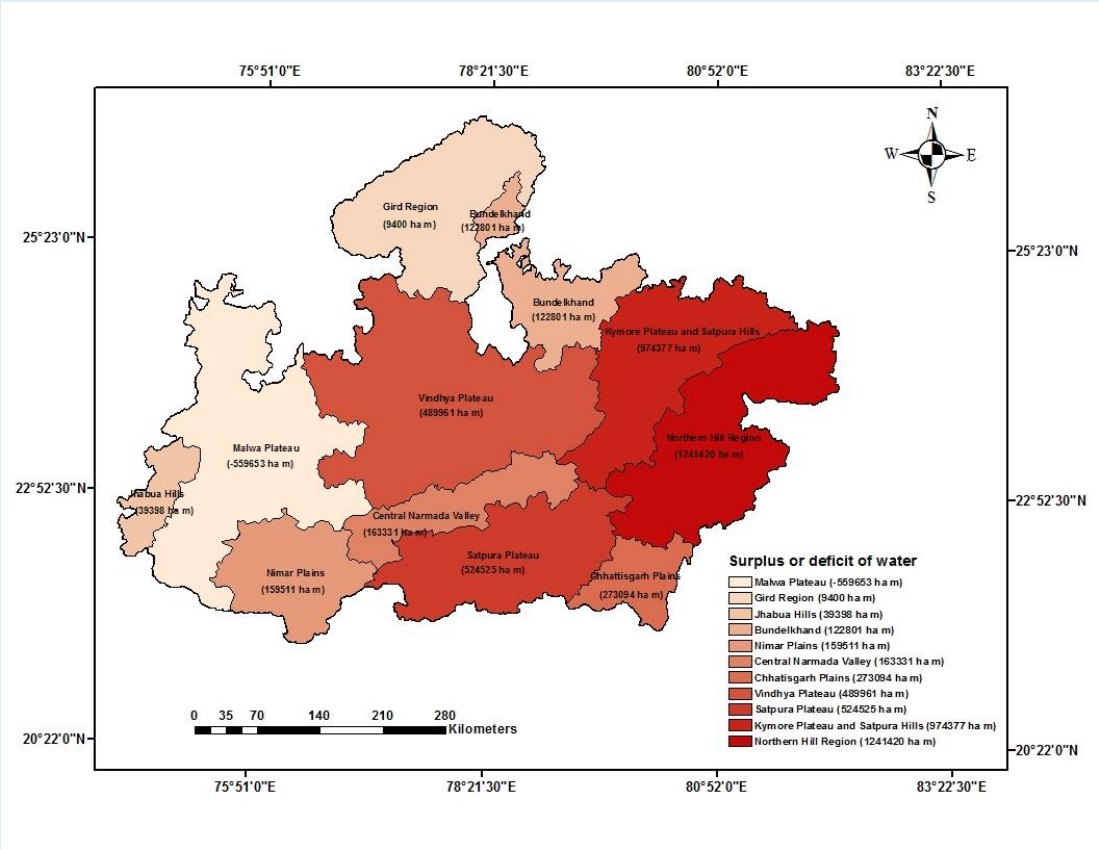


Fig 17 Water surplus-excess in different Agroclimatic zone, ha-m

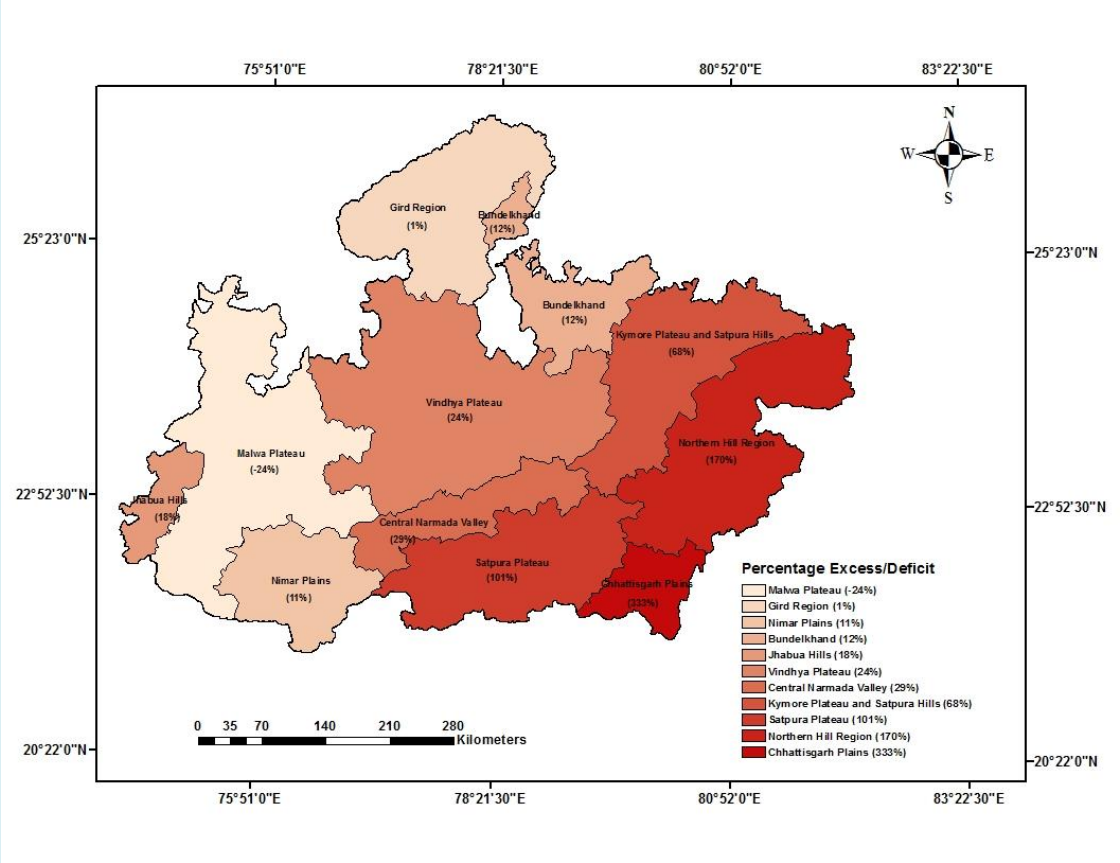


Fig 18 Water excess-deficit in percent in different Agroclimatic zone, ha-m

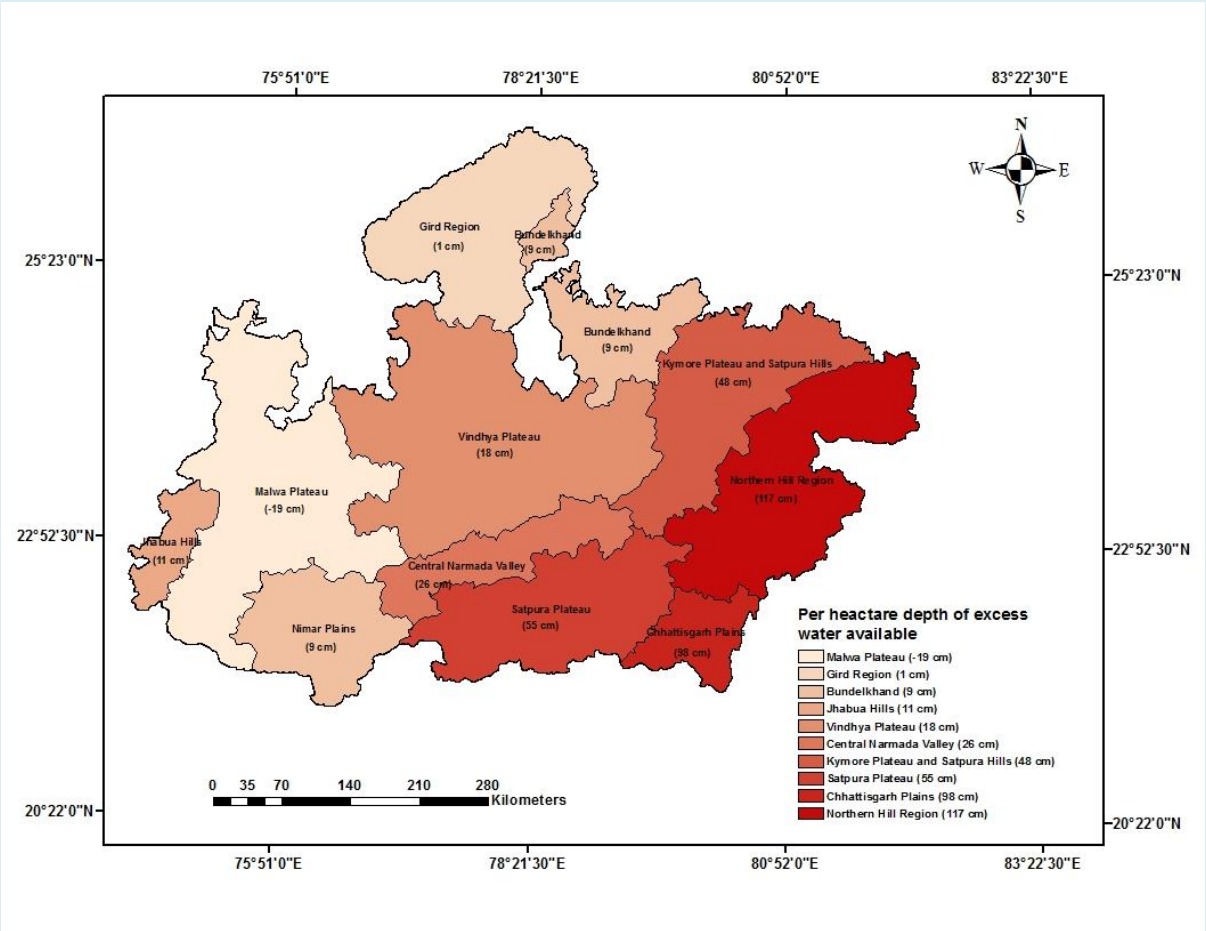


Fig 19 Depth of water available for future utilization in different Agroclimatic zone, cm

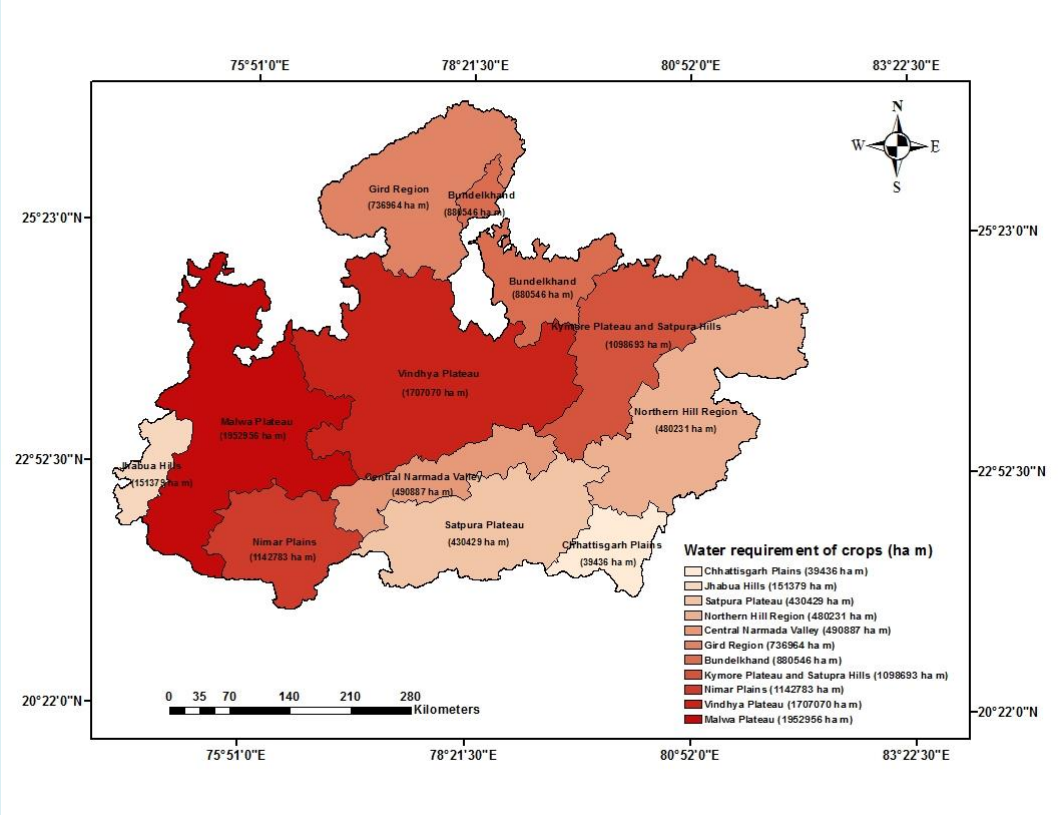


Fig 20 water requirement of crops in different Agroclimatic zone, ha m

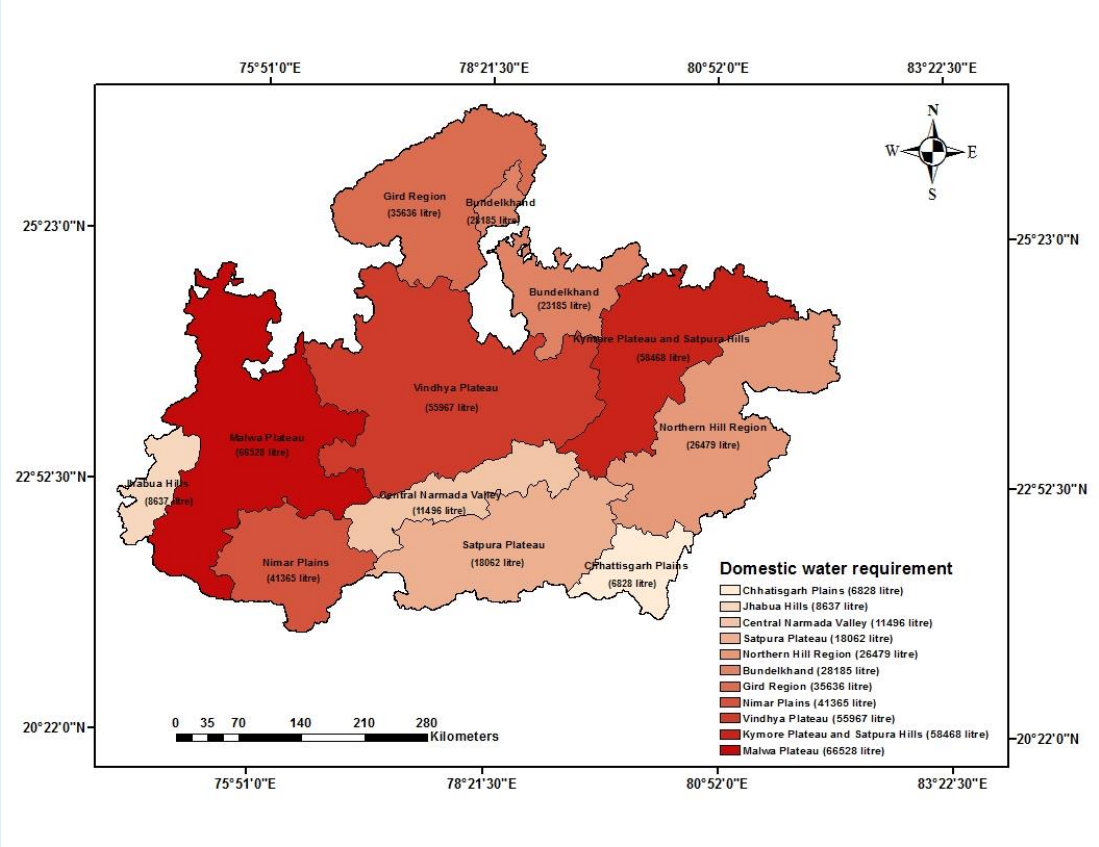


Fig 21 Domestic water requirement in different Agroclimatic zone, ha m

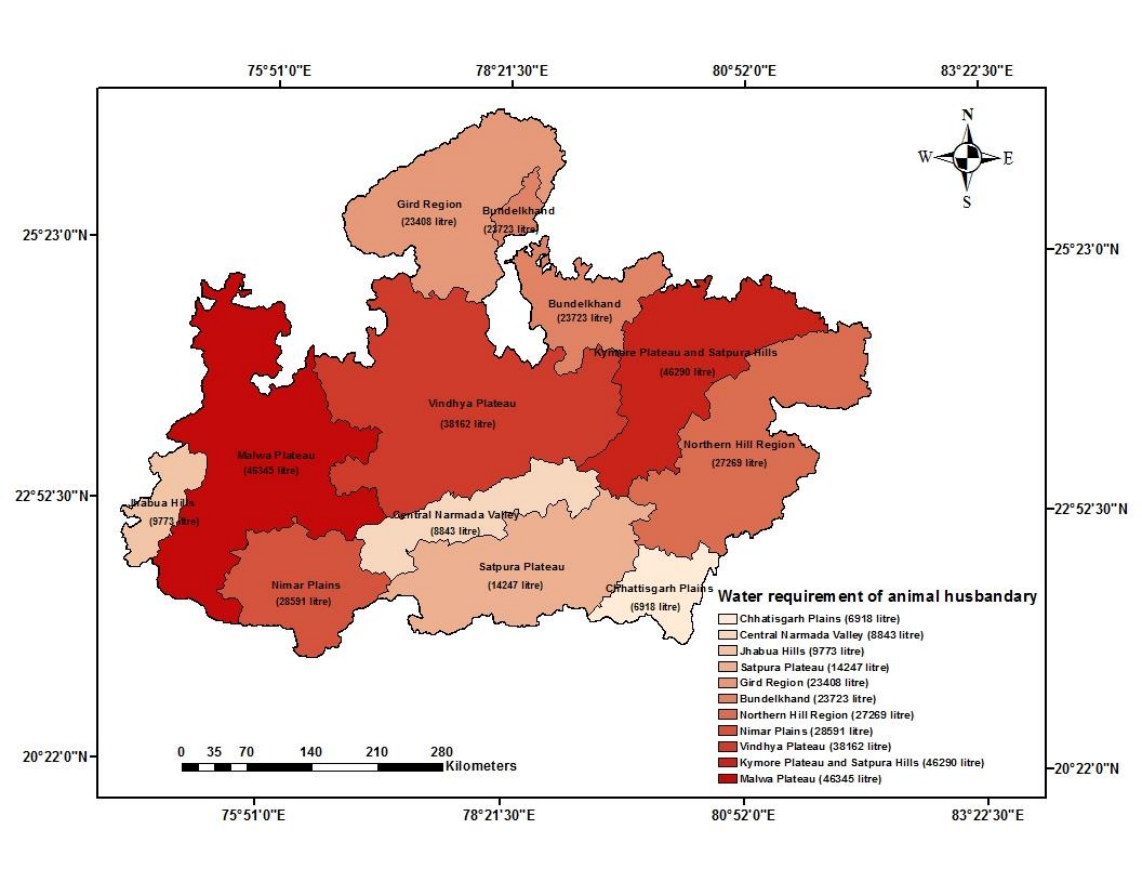


Fig 22 Livestock water requirement in different Agroclimatic zone, ha m

AGRICULTURAL WATER REQUIREMENT OF MADHYA PRADESH

The Economy of Madhya Pradesh depends mainly on the agricultural sector. More than 80% of the people of the state depend on this sector for their livelihood. The agricultural sector contributes around 46% to the state's economy. Agriculture is still one of the priority sectors of the state's economy as it supports the large chunk of the rural economy. Hence enhancement of water management opportunities will increase the resilience and adaptive capacity of agricultural communities to climate change, and help to achieve socio economic development plan's goals.

Land Utilization

The total geographical area of the Madhya Pradesh is classified in to different categories as shown in the Table 1. The total geographical area in the State is 30.756 million hectares. Among the districts, Chhindwara has the maximum geographical area of 11.849 lakh hectares (3.85% of the total geographical area) and Agar Malwa has the minimum geographical area of 2.725 lakh hectares (0.89% of the total geographical area).

Table 1. Classification of geographical area of the Madhya Pradesh according to land use pattern

S.No.	Category	Area (hectares)	% to total geographical area
1	Forest	86,90,816	28.26
2	Area under Non Agricultural Uses	21,61,511	7.03
3	Barren and Uncultivable Land	13,45,764	4.38
4	Permanent Pasture and Other Grazing Land	12,90,895	4.20
5	Land Under Misc. Tree Crops and Groves not Included in Net Area Sown	19,522	0.06
6	Cultivable Waste Land	10,08,120	3.28
7	Current Fallow	3,49,500	1.14
8	Fallow Lands other than Current Fallows	4,68,118	1.52
9	Net Area Sown	1,54,22,057	50.14
10.	Total Geographical area	3,07,56,303	100

Source: Directorate of Economics and Statistics, Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, 2013-14

Table 2. District wise land use classification of geographical area of the Madhya Pradesh

S.No.	District	Reporting Area for LUS ('000 ha)	Forests ('000 ha)	Not Available for Cultivation ('000 ha)		Other Uncultivated Land Excluding Fallow Land ('000 ha)			Fallow Land ('000 ha)		Net Area Sown ('000 ha)
				Area Under Non Agricultural Uses	Barren and Unculturable Land	Permanent Pasture and Other Grazing Land	Land Under Misc. Tree Crops and Groves not Included in Net Area Sown	Culturable Waste Land	Current Fallow	Fallow Lands Other Than Current Fallows	
1	Agar Malwa	272.6	6.1	25.1	30.3	22.1	0.0	08.0	0.3	0.9	179.8
2	Alirajpur	382.7	121.1	26.4	47.7	3.2	0.0	07.2	4.2	2.2	170.7
3	Anuppur	374.7	76.4	35.0	25.6	7.8	0.6	18.8	21.7	23.6	165.2
4	Ashoknagar	467.4	52.8	29.7	37.8	12.4	0.0	20.8	0.9	1.9	311.1
5	Balaghat	924.5	505.1	48.0	9.5	31.0	0.7	21.6	11.9	17.7	279.0
6	Barwani	529.8	183.1	28.4	73.1	4.8	0.0	06.7	1.4	2.7	229.6
7	Betul	1007.8	397.4	46.9	25.9	27.8	0.0	38.8	7.6	22.9	440.6
8	Bhind	445.2	8.8	37.5	22.4	16.6	0.5	11.4	2.0	4.7	341.3
9	Bhopal	277.9	44.1	33.4	3.9	30.2	0.0	05.3	1.1	4.4	155.4
10	Burhanpur	342.7	201.9	15.4	6.4	12.5	0.0	00.0	0.7	1.8	104.0
11	Chhatarpur	863.0	213.0	46.2	1.5	70.7	0.2	30.1	16.7	18.1	466.6
12	Chhindwara	1184.9	477.3	51.3	20.8	53.9	0.0	29.9	18.5	21.7	511.5
13	Damoh	728.6	267.5	32.1	57.5	36.3	0.3	10.0	2.7	4.2	318.0
14	Datia	307.2	29.4	18.1	16.2	6.0	4.0	12.9	4.2	4.8	211.6
15	Dewas	701.3	206.6	34.9	13.0	44.8	0.0	02.1	0.1	0.4	399.4
16	Dhar	819.5	119.7	59.0	75.7	46.9	0.0	13.0	1.1	2.2	501.9
17	Dindori	358.9	25.4	28.2	11.1	13.2	0.0	16.6	33.2	28.2	203.1
18	Guna	630.8	101.4	34.9	62.7	30.2	0.0	60.6	0.8	1.2	339.0
19	Gwalior	456.4	111.0	34.0	48.7	13.9	0.1	24.0	3.1	10.3	211.4
20	Harda	330.6	103.4	22.6	3.4	9.2	0.1	08.0	0.2	1.2	182.4
21	Hoshangabad	668.7	256.1	44.6	2.4	25.5	0.0	17.6	2.8	5.7	314.0
22	Indore	383.1	52.2	42.0	9.3	17.8	0.1	2.3	2.7	5.3	251.4
23	Jabalpur	519.8	76.7	41.5	36.9	39.9	0.1	24.6	8.6	12.7	278.7
24	Jhabua	293.1	11.0	32.4	35.0	4.5	0.0	18.1	1.1	1.2	189.8
25	Katni	493.1	97.1	38.2	37.1	39.5	0.0	31.4	13.9	18.9	216.8
26	Khandwa	775.6	305.3	93.6	8.3	49.1	0.0	0.0	6.3	9.2	303.8

S.No.	District	Reporting Area for LUS ('000 ha)	Forests ('000 ha)	Not Available for Cultivation ('000 ha)		Other Uncultivated Land Excluding Fallow Land ('000 ha)			Fallow Land ('000 ha)		Net Area Sown ('000 ha)
				Area Under Non Agricultural Uses	Barren and Unculturable Land	Permanent Pasture and Other Grazing Land	Land Under Misc. Tree Crops and Groves not Included in Net Area Sown	Culturable Waste Land	Current Fallow	Fallow Lands Other Than Current Fallows	
27	Khargone	818.7	246.9	47.4	36.2	56.8	0.0	19.3	2.2	7.6	402.3
28	Mandla	965.6	593.1	43.8	10.7	20.1	0.1	21.2	23.1	26.3	227.2
29	Mandsaur	551.8	40.6	79.5	43.7	13.6	0.1	15.2	0.9	1.0	357.2
30	Morena	501.7	51.4	41.0	88.8	18.7	0.0	21.3	3.9	4.8	271.7
31	Narsinghpur	513.7	136.2	25.6	1.0	24.1	0.2	10.6	2.9	3.8	309.3
32	Neemuch	393.6	94.4	48.4	39.8	9.3	0.0	16.9	0.7	0.8	183.2
33	Panna	702.9	299.7	43.9	22.5	11.1	0.0	44.8	3.6	5.4	272.0
34	Raisen	848.7	333.7	40.1	3.6	26.0	0.1	7.9	1.2	2.0	434.1
35	Rajgarh	616.3	17.6	44.7	29.0	48.8	0.3	30.3	2.1	4.4	439.1
36	Ratlam	486.0	34.3	41.0	29.8	27.2	0.1	14.7	0.5	0.9	337.5
37	Rewa	628.7	85.4	63.1	32.6	25.7	2.4	6.4	23.5	26.5	363.1
38	Sagar	1022.8	297.9	58.3	12.6	76.6	0.7	10.6	7.2	9.9	548.7
39	Satna	742.4	203.7	70.2	15.3	19.6	3.5	46.9	13.8	16.6	352.8
40	Sehore	656.4	172.4	42.3	9.5	26.8	0.0	5.5	0.2	0.8	398.9
41	Seoni	875.4	328.5	49.5	11.8	20.3	0.0	30.0	18.7	19.5	396.9
42	Shahdol	561.0	227.9	50.9	8.6	8.9	0.7	38.8	11.1	22.1	192.0
43	Shajapur	346.0	0.0	29.4	10.0	17.7	0.1	9.0	0.1	0.3	279.5
44	Sheopur	666.7	292.9	39.0	85.1	37.1	0.0	38.0	1.9	3.1	169.5
45	Shivpuri	984.1	330.6	61.6	37.1	25.1	3.8	51.4	4.0	12.5	458.0
46	Sidhi	471.9	195.1	38.0	3.8	5.3	0.0	31.3	16.3	12.6	169.5
47	Singrauli	567.7	239.6	51.1	13.2	12.8	0.0	42.5	24.7	16.9	167.1
48	Tikamgarh	504.0	69.2	37.6	54.8	18.9	0.2	22.5	2.4	20.2	278.4
49	Ujjain	609.9	3.1	58.8	5.9	32.3	0.1	7.6	0.5	1.8	499.7
50	Umaria	450.3	236.7	35.2	8.6	14.5	0.2	17.7	14.8	17.7	104.9
51	Vidisha	730.2	109.6	41.9	9.2	23.8	0.2	8.2	1.3	2.4	533.6
	State Total	**30756.3**	**8690.8**	**2161.5**	**1345.8**	**1290.9**	**19.5**	**1008.1**	**349.5**	**468.1**	**15422.1**

Source: Directorate of Economics and Statistics, Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, 2013-14

Forests

Forests are of paramount importance not only from the economic point of view but also from the ecological point of view. It has various roles in maintaining ecological balance and moderation of environment besides providing livelihood opportunities to people depending on forests. However, growing human population, and consequent large scale urbanization, industrial development and political consolidation have currently put heavy demand on forest for fuel, fodder, food, medicine and small timber causing degradation of forests.

Forest area is defined as an area recorded as forest in the government records. Madhya Pradesh has highest recorded forest area in the country with an area of 86,90,816 hectares constituting 28.26 percent of the total geographical area of the state (i.e. 3,07,56,303 hectares). From the Table 2 it is observed that the largest forest area is present in Mandla District 5,93,139 hectares (6.82%) followed by Balaghat 5,05,078 hectares (5.81%), Chhindwara 4,77,290 hectares (5.49%) and least in Ujjain 3,149 hectares (0.04%) and Shajapur has almost no forest cover, of total forest area of the state's. Since the area covered under forests does not vary significantly from year to year, the water loss through evapo-transpiration is kept constant while budgeting the water for entire state as well for the districts.

Area under Non Agricultural Uses

The area covered under this category is 21,61,511 hectares which is 7.03% of the total geographical area. In this category, district Khandwa has highest area 93,591 hectares (4.33% of total area under non agricultural uses) followed by Mandsaur 79,534 hectares (3.68%) and Satna 70,211 hectares (3.25%); and least area in Burhanpur 15,393 hectares (0.71%). For such places the evaporation from the bare soil surface has been taken in to account for water budgeting.

Barren and Uncultivable Land

The barren and uncultivable land is around 13,45,764 hectares which is 4.38% of the total geographical area. Under this category, district Morena has highest area 88,824 hectares (6.60% of total area under barren and uncultivable land) followed by Sheopur 85,109 hectares (6.32%) and Dhar 75,743 hectares (5.63%); and least area in Narsinghpur 1,020 hectares (0.08%). For such places the evaporation from the bare soil and transpiration from the forest lands have been taken in to account for water budgeting for districts.

Permanent Pasture and other Grazing Land

Table 1 indicates that the total area under this category is 12,90,895 hectares which is about 4.20% of the total geographical area of the state. From the Table 2 it is clearly observed that the district Sagar has largest area 76,643 hectares (5.94% of the total permanent pasture and other grazing land) under this group followed by Chhatarpur 70,721 hectares (5.48%) and Khargone 70,772 hectares; and Alirajpur has least area 3,208 hectares (0.25%). These lands contribute water loss through

evapo-transpiration and need to be included in the computation of water budgeting of the district.

Land under Miscellaneous Tree Crops and Groves not Included in Net Area Sown

Total area of 19,522 hectares with 0.06% of total geographical area is covered under miscellaneous tree crops and groves in the state (shown in Table 1). Datia has largest area 3987 hectares (20.42% of the total land under miscellaneous tree crops and groves) followed by Shivpuri 3821 hectares (19.57%) and Satna 3471 hectares (17.78%). Almost no area observed under this category in the districts of Alirajpur, Barwani, Burhanpur, Guna, Morena, Panna and Sheopur (Table 2). These lands also contribute water loss through evapo-transpiration and it is included while computing water budget of the districts.

Cultivable Wasteland

The total area under this category is reported to be 10,08,120 hectares, which is 3.28% of the total geographical area of the state as shown in Table 1. The largest area is reported in the district Guna 60,624 hectares which is 6.01% of the total cultivable waste land followed by Shivpuri 51,434 hectares (5.10%) and Satna 46,867 hectares (4.65%). But the water loss through evaporation and transpiration is considered from such areas for computing water budget of such districts.

Current Fallow

The total area under current fallow category is observed to be 3,49,500 hectares which is 1.14% of the total geographical area of the state. From Table 12 the largest area observed under this category in District Dindori is 33,198 hectares (9.50% of the total area under current fallow) followed by Singrauli 24,666 hectares (7.06%) and Rewa 23,492 hectares (6.72%); and least area is found in Shajapur 67 hectares (0.02%). The rainfall received on such area and losses through either evaporation or transpiration do form the component of water balance in such districts.

Fallow Lands other than Current Fallows

Total area of 4,68,118 hectares with 1.52 % of the total geographical area is under this category. Largest area is found in Dindori 28,178 hectares (6.02% of the total area under fallow land other than current fallow) followed by Rewa 26,510 hectares (5.66%) and Mandla 26,286 hectares (5.62%); and least area in Shajapur 258 hectares (0.06%). Water losses through evapo-transpiration are considered for budgeting of water in respective districts.

Net Area Sown

Table 1, further exhibits the fact that Madhya Pradesh has the net sown area 1,54,22,057 hactares with 50.14% of the total geographical area of the state. Under this category Sagar has largest net shown area of 5,48,740 hectares (3.56% of the total net shown area) followed by Vidisha 5,33,611 hectares (3.46%) and Chhindwara 5,11,495 hectares (3.32%). The least area under net shown area category is found in Burhanpur 1,04,016 hectares, which is 0.67% of the total net

shown area (Table 2). The area under each crop is taken in to account to calculate its water requirement and water surplus and deficit is indicated in each district.

Table 3. Land Utilization pattern and water resources of Madhya Pradesh

S.No.	Particulars	
1	Total Geographical Area (ha)	30756303
2	Forest Area (ha)	8690816
3	Gross Cropped Area (ha)	24047027
4	Net Cultivated Area (ha)	15422057
5	Cropping Intensity (%)	143
6	Annual Rainfall (mm)	1170
7	Total Rain Water Resources (ha-m) (Item No. 1 $\times$ 7)	35984875

Source: Directorate of Economics and Statistics, Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, 2013-14

Gross Cultivated Area and Cropping Intensity

Table 3 indicates that Madhya Pradesh has gross cropped area of 2,40,47,027 hectares with average cropping intensity of 143%. This indicates that about 43 per cent of the cultivated area is double cropped or crops are grown in rabi or summer season with the help of other irrigation facilities or available soil moisture in the field. However for computation of water requirement of the crops, season and duration of crop is considered.

Rain Water Resources

Madhya Pradesh has normal average annual rainfall of 1170 mm and it is dependent on rainfall for its water requirements. The total rain water resource is to be finding out 35984875 ha-m. The similar procedure is followed while computing the water resources of different districts. Although normal rainfall is considered for entire state, the variation for district persists due to variability of rainfall and geographical area among the various districts.

Water Requirement of the Crops

Soybean has largest cultivated area of 65,43,581 hectares among all crops of the state followed by Wheat 61,23,044 hectares, Gram 27,74,323 hectares and Rice 18,81,546. The total water requirement for cultivation of Soybean, Wheat, Gram and Rice in Madhya Pradesh are 25,88,618 ha-m, 35,62,075 ha-m, 14,85,577 ha-m and 14,01,244 ha-m respectively (Table 4). The variations in the water requirement of the crops are due to season, duration and occupied area of the crops. Most of the crops grown in kharif season in rain fed condition but the crops grown in rabi season utilize residual soil moisture for their growth and maturity. The crop water requirement for field crops, fruits and vegetable crops and plantation and other crops are given in Table 4. Field crops have maximum crop water requirement of 1,21,11,075 ha-m followed crop water requirement for fruits and vegetable 4,03,533 ha-m and plantation and other crops 8,22,353 ha-m.

Table 4. Water requirement of crops in Madhya Pradesh

Water requirement of field crops			
S.No.	**Crops**	**Area (ha)**	**CWR (ha-m)**
1	Rice	1881546	1401244
2	Jowar	247829	116866
3	Bajra	191328	75689
4	Maize	851639	440569
5	Ragi	336	87
6	Wheat	6123044	3562075
7	Barley	83559	46401
8	Other Cereals and Millets	201851	97726
9	Gram	2774323	1485577
10	Arhar (Tur)	395709	234251
11	Other Pulses	1541040	751946
12	Sugarcane	102064	153003
13	Groundnut	215619	114824
14	Castor seed	2458	2929
15	Sesamum	269597	135524
16	Rapeseed and Mustard	702055	356696
17	Linseed	88825	47563
18	Soyabean	6543581	2588618
19	Niger seed	68873	50086
20	Sunflower	76	27
21	Safflower	21	9
22	Other Oilseeds	12127	6774
23	Cotton	573812	438827
24	Jute	1054	812
25	Mesta	299	200
26	Sanhemp	3091	2555
27	Other Fibres	298	200
	Total	**22876054**	**12111075**
Fruits and Vegetables			
28	Mango	5641	8985
29	Banana	18637	38415
30	Citrus Fruits	17585	22517
31	Grapes	103	103
32	Papaya	1647	2685
33	Other Fruits	6366	10140
34	Potato	80955	73413
35	Sweet Potato	4776	3201
36	Onion	79260	133670
37	Other Vegetables	158465	110404
	Total	**373435**	**403533**

Plantation and Other Crops			
38	Chillies	71877	77422
39	Ginger	10668	12832
40	Turmeric	2964	3551
41	Betel nut	14333	16115
42	Garlic	80545	128291
43	Coriander	129653	181761
44	Other Condiments and Spices	35195	42965
45	Opium	3615	3441
46	Tobacco	100	58
47	Other Plantation Crops	40719	72487
48	Fodder Crops	399022	272400
49	Other Non Food Crops	8743	11031
	Total	**797434**	**822353**
Grand Total (Field Crops+ Fruits and Vegetables+ Plantation and other crops)		**24046923**	**133336962**

Source: Directorate of Economics and Statistics, Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, 2013-14

WATER NEEDS FOR DOMESTIC AND OTHER SECTORS OF MADHYA PRADESH

Growing population coupled with sustainable developmental efforts has an increasing stress on water resources. The uneven distribution over time and space of water resources and their modification through human use and abuse are sources of water crises in many parts of the world. All these result in intensifying the pressure on water resources leading to tensions, conflict among users and excessive pressure on the environment. This demands the planners and policy makers for a proper management of water resources. This, in turn, calls for a reliable and adequate statistics on water and related aspects.

Domestic Water Requirement

Madhya Pradesh has total human population 7,26,26,809 during the year 2011 (Census 2011). For domestic purpose per capita water requirement is 135 litre/day as per the WHO recommendations. According to this the total domestic water requirement is 3,58,283.1 ha-m. Although the water requirement for urban and rural areas are varies a lot, this figure is adopted for understanding of the gravity of the situation.

Animal Husbandry Water Requirement

As per the 12th live stock census 2012, Madhya Pradesh has total live stock population of 7,10,19,787. In cattle population, the state has largest population of bovine (2,77,90,355) followed by indigenous cattle (1,87,61,389), buffalo (81,87,989), goat (80,13,936), cross breed cattle (8,40,977) and sheep (3,08,953). Other live stock enterprises which demand for water includes horse and ponies, mules, donkey, camels, pigs, dogs, rabbits, elephants, fowls, ducks, turkeys and other poultry etc. Water requirement for human and live stock populations are given in Table 1.

Industrial Water Requirement

The main sources of water for the industrial sector are groundwater and surface water. Groundwater has emerged as an important source to meet the water requirements of industries. Industrial activity requires large amounts of freshwater for activities such as boiling, cleaning, air-conditioning, cooling, processing, transportation and energy production. As the country rapidly industrializes, greater quantities of water will be required. The positive side of this trend is that water used in industrial processes can be recycled, unlike in agriculture where very little of it is actually consumed. In India, the water demand for the industrial sector is on a rise and will account for 8.5 per cent of the total freshwater abstraction in 2025, the current level of 6 per cent of the total freshwater abstraction by the industries in 2010. (FICCI Water Mission, New Delhi, 2011).

Table 1. Water requirement for human and live stock population in Madhya Pradesh

S. No.	Particulars	Number	Water Requirement (ha-m)
1	Human Population (135 l/day)	72626809	357868.60
2	Live Stock Population		
i	Cross breed Cattle (150 l/day)	840977	4604.35
ii	Indigenous Cattle (100 l/day)	18761389	68479.07
iii	Buffalo (150 l/day)	8187989	44829.24
iv	Bovine (150 l/ day)	27790355	152152.19
v	Sheep (10 l/day)	308953	112.77
vi	Goat (10 l/day)	8013936	2925.09
vii	Horse and Ponies (32.5 l/day)	18803	22.31
viii	Mules (32.5 l/day)	6989	8.29
ix	Donkey (32.5 l day)	14916	17.69
x	Camels (115 l/day)	3422	14.36
xi	Pigs (10 l/day)	175253	63.97
xii	Dogs (5 l/day)	433367	79.09
xiii	Rabbits (0.64 l/day)	3679	0.09
xiv	Elephants (150 l/day)	1045	5.72
xv	Fowls (0.25 l/day)	6429958	58.67
xvi	Ducks (0.25 l/day)	20016	0.18
xvii	Turkeys (0.25 l/day)	4413	0.04
xviii	Other Poultry (0.25 l/day)	4327	0.04
	Total		273373.16
	Grand Total		631241.76

Source: 19th live stock census, 2012

District wise water budget

Agroclimatic Zone I - Chhattisgarh Plains

The state of Madhya Pradesh is divided into eleven agroclimatic zone. The Agroclimatic zone I – Chhattisgarh Plains a single district in purview of Madhya Pradesh State. It comes under Rice zone having red and yellow (medium) soils. The zone has total geographical area of 924500 ha, out of which forest area is 54.6 %. Net area sown is 30.2 %. Out of total Net Sown area of 279017 ha, the fallow land including current fallow is 10.6%. District land utilization is presented in Table 1.

Rainfall analysis

Annual normal rainfall is 1471.6 mm. On an average 90 % of this rainfall occurs during monsoon i.e. June to September, 8% in winter i.e. late December and 2 % in summer. Maximum rainfall occurs in the month of July narrowly followed by the month August. The pattern of annual rainfall occurred in years 1970 to 2014 is presented in Fig. 1. The record also shows maximum ever rainfall of 3210 mm (1994) was occurred in the Balaghat. The annual rainfall exceeded 44.2 % more than the normal annual rainfall.

Domestic and livestock water needs

Total human population of the zone is 1701156 as per Census 2011. Total human water needs of the zone are 8382 ha-m. Table 2 illustrates water requirement towards human needs as well as for live stock. Live stock population comprises of cattle both cross breed and indigenous, buffalo, bovine, sheep, goat, horses and ponnies, mules, donkey, pigs, dogs, rabbits, fowls, ducks, turkey and other poultry. The indigenous cattles are about 52 times more than the cross breed cattle. This indicates that the zone has tremendous scope for breeding improvement programmes. Bovine is the main cattle class (717817) followed by population of buffaloes (141034). There is no sheep found in the district Balaghat as well as the population of donkey and camels are also negligible. Goats are found in plenty and are almost equal to the Fowls i.e. 228211.

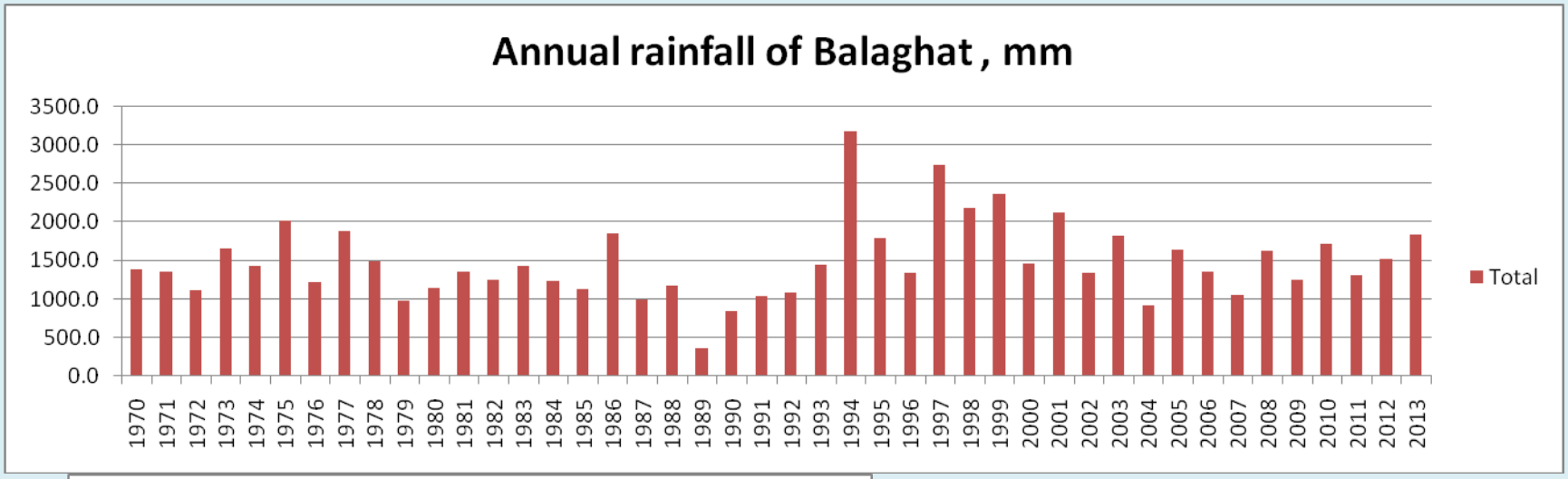
Water requirement of crops

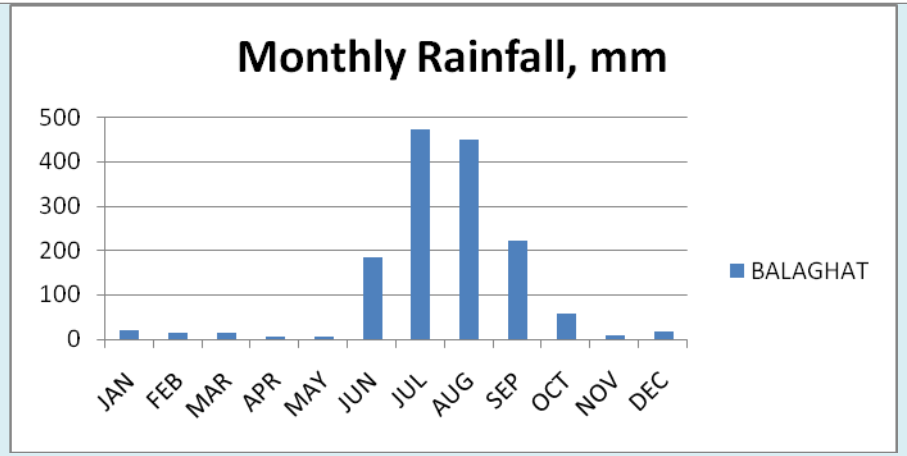
The zone is a Rice zone has 249248 ha under rice (Kharif) and also has 9399 ha under summer rice. Wheat is cultivated in 17520 ha. Other major crops are gram (7492 ha), Pigeon pea (4343 ha), rapeseed and mustard (3061 ha) and maize (4292 ha). Apart from this other Pulses (rabi) are also taken in 16542 ha and in Kharif it occupies 2688 ha Table 3 A. In Table 3 B the water required by various vegetables and fruit trees are listed. Being only one district in this zone in Madhya Pradesh the zonal total seems to be low. Coriander is taken in 333 ha, potato in 371 ha and onion in 196 ha. Area under other vegetable (rabi) is 1125 ha. Based on growing period, crop coefficient values, the water requirement of all the crops were worked out and presented in Table 3. However, based on irrigated area the water requirement of major crops were also calculated and presented Fig. 2 to Fig 4. For the zone rice is the major kharif crops and its water requirement is 11772 ha-m. Maize is another crop but its water requirement is very less than rice i.e. only 5352 ha-m (Fig.2). Water requirement of wheat, rice summer, gram and sugarcane is respectively, 6730 ha m, 6921 ha m, 2652 ha m, 1598 and ha-m Fig. 3. Fig 4 shows requirement of water towards pulses where other than arhar, pulses requires 5462 ha-m water.

Table 1 Total Area and Classification of Area In Each District of Chhattisgarh Plains MADHYAPRADESH State for the year ending 2013- 14															
DISTRICT NAME	Reporting Area For Land Utilization Statics			Not Available For Cultivation			Other Uncultivated Land Excluding Fallow Land			Fallow Land		Total	Net Area Sown	Total Cropped Area	Area Sown more than once
		Forests	Area Under Non Agricultural Uses	Barren and Unculturable Land	Total	Permanent Pastures and Other Grazing Lands	Land Under Misc Tree crops and Groves not Included in Net Area	Culturable Waste Land	Total	Fallow Lands Other than Current Fallows	Current Fallows				
(1)	(2)	(3)	(4)	(5)	6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
BALAGHAT	924500	505078	48042	9454	57496	30981	735	21597	53313	17655	11941	29596	279017	346752	67735
Total	**924500**	**505078**	**48042**	**9454**	**57496**	**30981**	**735**	**21597**	**53313**	**17655**	**11941**	**29596**	**279017**	**346752**	**67735**

Table 2 : Live stock and Human water needs of ACZ I

	Balaghat	Zone Total
Cross breed Cattle	10871	10871
Water Req. (l/day)	1630650	1630650
Indigenous Cattle	565912	565912
Water Req. (l/day)	56591200	56591200
Buffalo	141034	141034
Water Req. (l/day)	21155100	21155100
Bovine	717817	717817
Water Req. (l/day)	107672550	107672550
Sheep	3	3
Water Req. (l/day)	30	30
Goat	225972	225972
Water Req. (l/day)	2259720	2259720
Horse & Ponies	748	748
Water Req. (l/day)	24310	24310
Mules	399	399
Water Req. (l/day)	12967.5	12967.5
Donkey	9	9
Water Req. (l/day)	292.5	292.5
Camels	9	9
Water Req. (l/day)	1035	1035
Pigs	5386	5386
Water Req. (l/day)	53860	53860
Dogs	10274	10274
Water Req. (l/day)	51370	51370
Rabbits	162	162
Water Req. (l/day)	103.68	103.68
Elephants	123	123
Water Req. (l/day)	18450	18450
Fowls	228211	228211
Water Req. (l/day)	57052.75	57052.75
Ducks	913	913
Water Req. (l/day)	228.25	228.25
Turkeys	6	6
Water Req. (l/day)	1.5	1.5
Other Poultry	373	373
Water Req. (l/day)	93.25	93.25
TWR - lpd	191437236	191437236
TWR - ha m	6918	6918
Human WR , ha-m	1701156	1701156





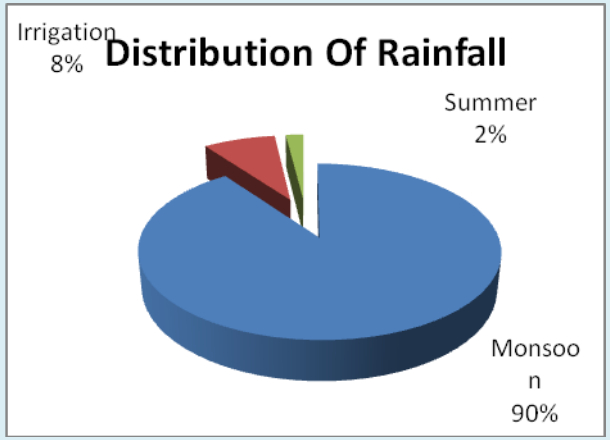


Fig. 1 Rainfall analysis at district Balaghat, Agro-Climatic Zone – I Chhattisgarh Plains

Water budget

Rainfall is the prime and sole input of water to any area. The agroclimatic zone I (ACZ I) - Chhattisgarh Plains receives total quantum of water towards rainfall as 779721 ha-m. National Commission on Agriculture has laid down norms for water budgeting of an area and as per its estimate the losses of water as evaporation, surface water flow and ground water flow out of the area is calculated in present estimation. Similarly, addition of water into the area as runoff generated from the zone, addition of soil moisture and to the ground water is also computed. The water budget so generated for ACZ I is presented in Table 4. The immediate evaporation losses that occurs during the rainfall is taken as 17.5% of total rainfall and it is 136451 ha-m for the zone. 28.7% rainfall converts into surface flow and it is 223780 ha-m. It is considered that 10.549 % (37177 ha-m) of surface flow goes out of the zone. Ground water also adds to the surface flow and it is taken as 23.739% of surface flow. Thus, surface flow arrives to be 352418 ha m which is 45.198% of total precipitation.

Evaporation takes place from open water body, soil surface, forest and vegetation and also from rise of water table, and, respectively it is taken as 7.916% (27897 ha-m) of total surface flow, 31.504% (109299 ha-m) of total soil moisture storage, 30.826% (106947 ha-m) of total soil moisture and 18.451% (30920 ha-m) of total ground water. Part of rainfall as recharge enriches ground water and it is 12.5 % (97465 ha-m).

Table 3A : Water requirement of field crops in Chhattisgarh Plains

Crop Name	Area Covered (ha)	CWR (ha-m)
Rice (Kharif)	249248	158771
Rice (Summer)	9399	9484
Jowar (Kharif)	81	33
Jowar (Rabi)	-	-
Bajra	-	-
Maize	4292	1904
Ragi	220	49
Wheat	17520	9173
Barley	-	-
Other Cereals and Millets (Kharif)	9757	4040
Other Cereals and Millets (Rabi)	1	0
Gram	7492	3611
Arhar (Tur)	4343	2200
Other Pulses (Rabi)	16542	7480
Other Pulses (Kharif)	2688	1079

Crop Name	Area Covered (ha)	CWR (ha-m)
Sugarcane	1847	2160
Groundnut	630	288
Castor seed	17	18
Sesamum	1311	564
Rapeseed and Mustard	3061	1352
Linseed	14195	6841
Soyabean	45	15
Niger seed	102	65
Sunflower	2	1
Safflower	-	-
Other Oilseeds	-	-
Cotton	-	-
Jute	-	-
Mesta	75	43
Sanhemp	41	30
Other Fibres	-	-

Table 3B : Water requirement of fruits and vegetables crops in Chhattisgarh Plains

Crop Name	Area Covered (ha)	CWR (ha-m)
Chillies	238	236
Ginger	182	193
Turmeric	90	95
Betel nut	-	-
Garlic	148	213
Coriander	333	412
Other Condiments and Spices	-	-
Mango	78	112
Banana	16	30
Citrus Fruits	8	9
Grapes	-	-
Papaya	-	-
Other Fruits	23	33
Potato	371	305
Sweet Potato	99	57
Onion	196	299
Other Vegetables (Kharif)	758	435
Other Vegetables (Rabi)	1125	723
Opium	-	-
Tobacco	-	-
Other Plantation Crops	-	-
Fodder Crops	177	103
Other Non Food Crops	1	1

Table 4 - Water budgeting of Chhattisgarh Plains, ha-m

S.N	Particulars	Balaghat
1	Normal rainfall, ha-m	779721
2	Immediate evaporation (17.5%)	136451
3	Surface flow (28.7%)	223780
4	From outside state(10.549% of total surface flow)	37177
5	To GW from flood flows (-4.851% of total surface flow)	-17096
6	From GW to surface flow(23.739% of total surface flow)	83661
7	From irrigated area to surface flow(7.067% of total surface flow)	24905
8	Total surface flow(45.198% of total ppt)	352418
9	Evaporation losses from reservoirs and tanks (7.916% of total surface flow)	27897
10	Flow into seas and outside state (43.445% of total surface flow)	153108
11	Utilizable surface flow (48.639% of total surface flow)	171413
12	Water available for ground water storage (12.5%)	97465
13	From streams and flood flows to GW(4.851% of total surface flow)	17096
14	From irrigation to GW addition (S.N.15-(12+13))	53017
15	Total GW (21.492% of total ppt)	167578
16	Evaporation and rise of water table (18.451% of total GW)	30920
17	Regeneration into streams(49.924% of total GW)	83661
18	GW available utilization(31.625% of total GW)	52996
19	Total utilizable surface + GW (S.N. 11+18)	224409
20	Soil moisture storage (41.3% of normal rainfall)	322025
21	From irrigated area to soil moisture(7.067% of total surface flow)	24905
22	Total soil moisture storage (44.495% of total ppt)	346937
23	Evaporation losses from soil moisture (31.504% of total soil moisture storage)	109299
24	Evap. losses from forest and other veg. (30.826% of total soil moisture)	106947
25	Soil moisture available for ET from crops (37.673 % of total soil moisture)	130702
26	Water requirement of crops	39436
27	Water requirement of animal husbandry	6918
28	Domestic water requirement	6828
29	Industrial Water requirement @ 6 % of available fresh water	46469
30	Water available for utilization (S.N. 19+25)	355111
31	Water required for different sectors (26+27+28+29)	99651
32	Surplus or deficit of water in the district (30-31)	255460

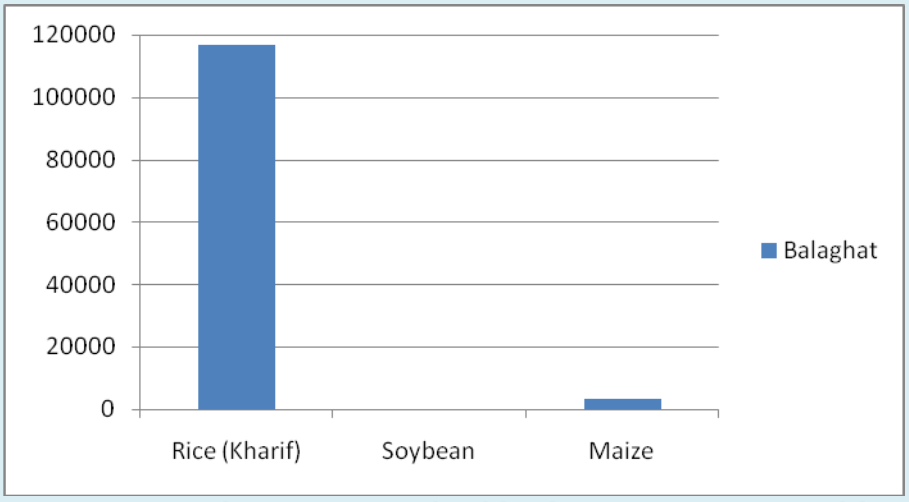


Fig. 2 Crop water requirement of major kharif crops of ACZ I -Chhattisgarh Plains in ha m

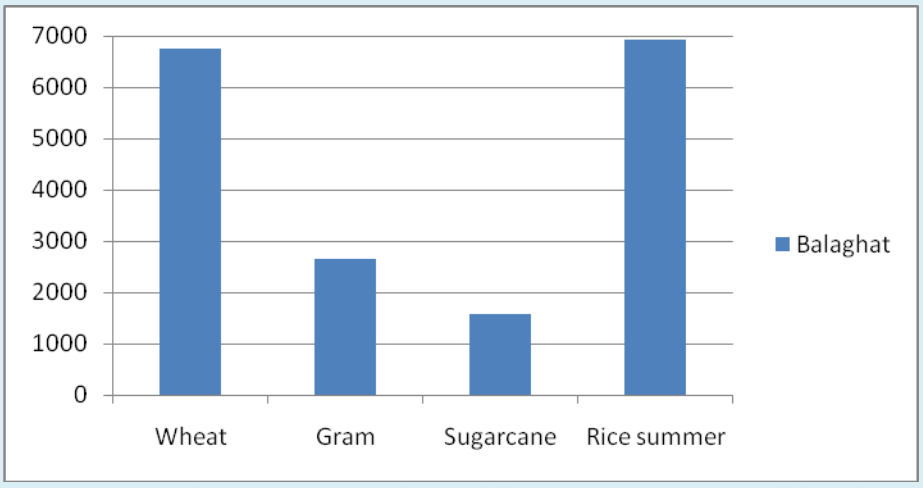


Fig.3 Crop water requirement of major rabi crops of ACZ I -Chhattisgarh Plains in ha m

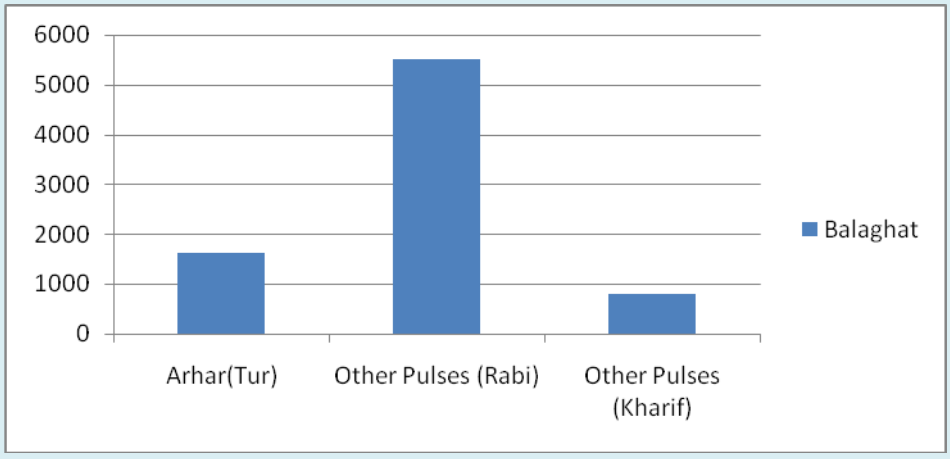


Fig. 4 Crop water requirement of pulse crops of ACZ I -Chhattisgarh Plains in ha m

There is movement to ground water from streams and flood flows which is -4.851 % (-17096 ha-m) of total surface flow. The total utilizable surface ground water for the ACZ I is computed as 355111 ha-m. The soil moisture increases due to rainfall as well as from irrigation. 41.3% of rainfall and 7.067% of total surface flow is considered as soil moisture storage. Total zonal soil moisture storage is 346937 ha-m and out of this 130702 ha-m is available as ET for the crops.

Utilization of water takes place in four major categories. These are, domestic and animal water needs, crop water requirement and requirement of water for industrial and recreation. Water needs of different sectors in districts of ACZ I is presented in Fig. 5. Total crop water requirement of the zone is 39436 ha-m. In comparison to the crop water demand, the water demand towards domestic and animal husbandry is very low as it is respectively 6828 ha m and 6918 ha-m. The industrial demand is computed as 6% of available water thus total zonal demand comes out as 46469 ha-m.

Total water needs and supply of different districts of ACZ I is presented in Fig. 6. The excess of water is also shown in the figure. The water available for utilization at zonal level is 355111 ha-m. As for as the excess water concerns the zone has 255460 ha-m of surplus water and this is 333% of total utilization. Considering net sown area as 279017 ha the average depth of excess water available per hectare is 98 cm. It means, the future plans to enhance crop production or alternate cropping may be based on this 98 cm depth of water. An abstract in pictorial form is provided in Fig 7.

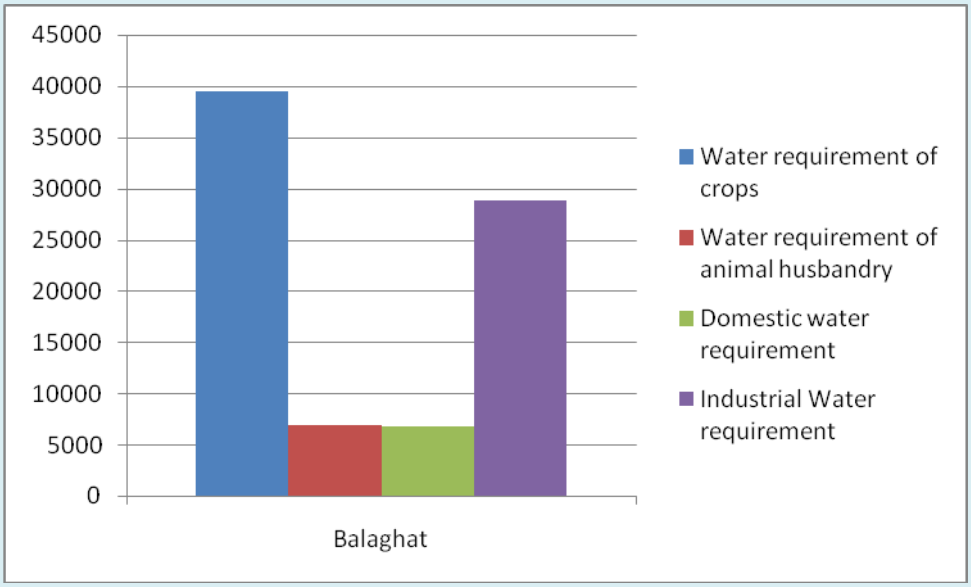


Fig. 5 Water needs of different sectors in districts of ACZ I Chhattisgarh Plains (ha-m)

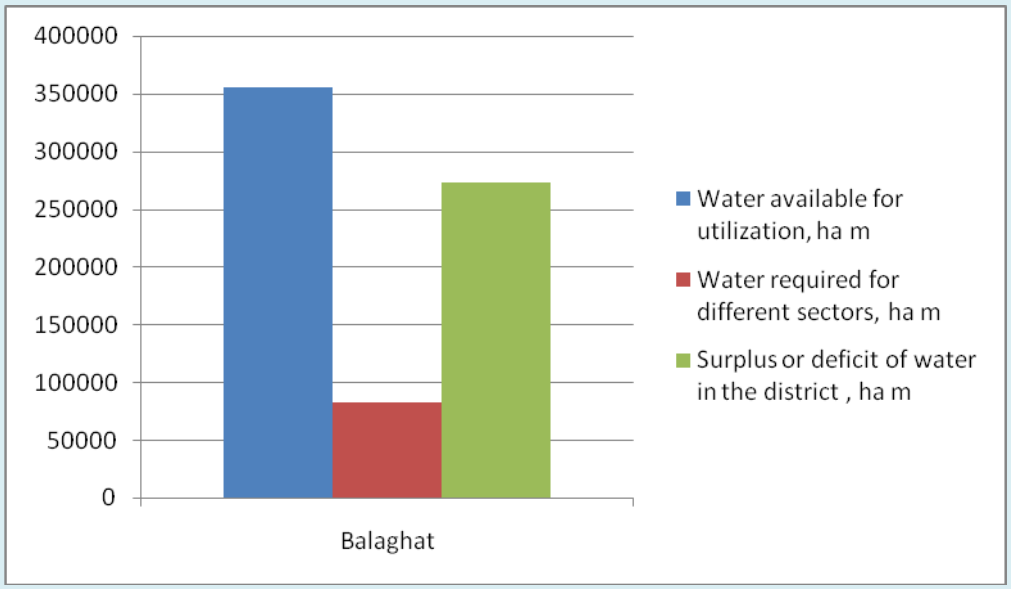


Fig. 6 Total Water needs and supply of different districts of ACZ I Chhattisgarh Plains (ha-m)

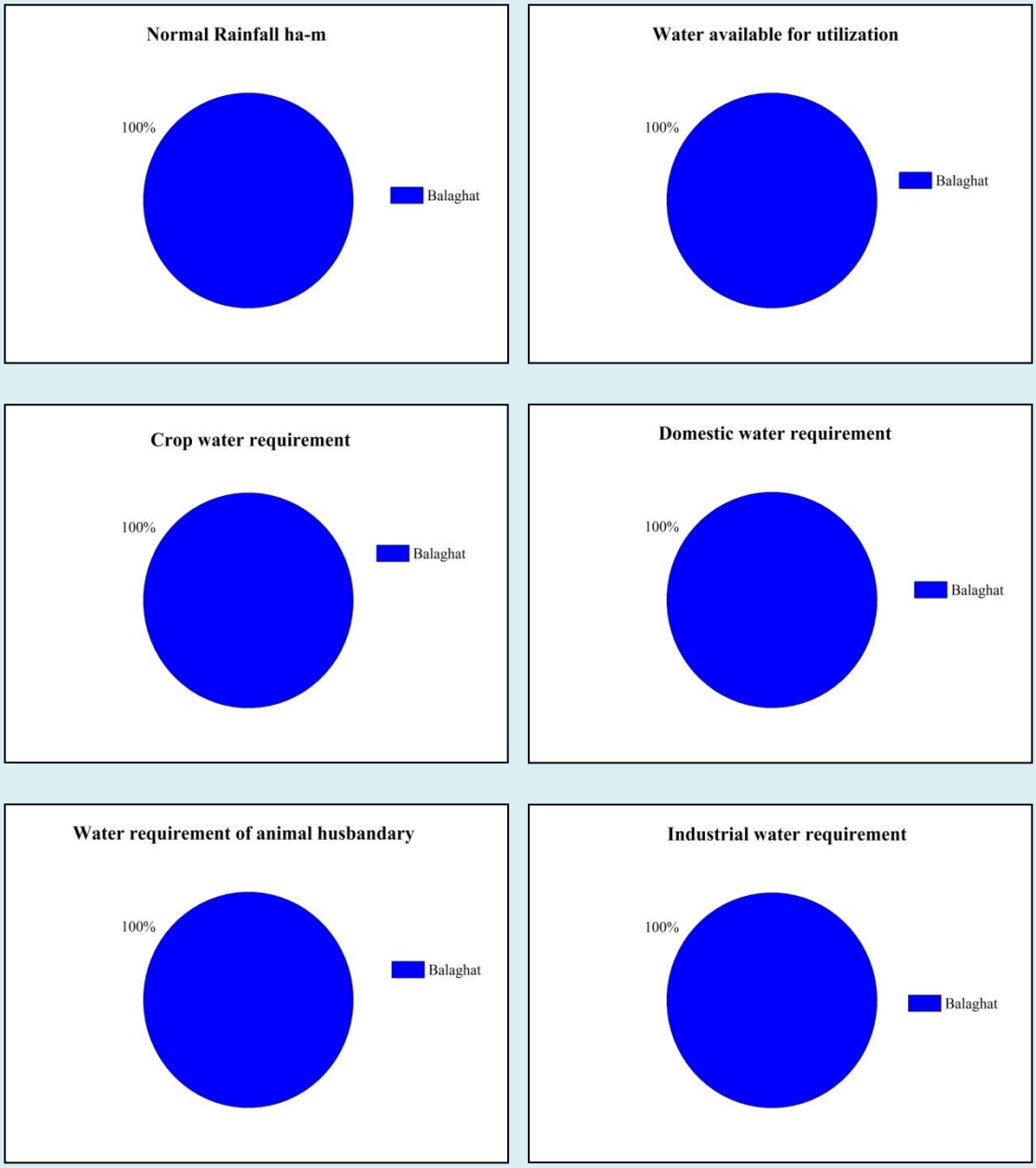


Fig. 7 Abstract of water of different districts of ACZ-I - Chhattisgarh Plains (ha-m)

Agroclimatic Zone II - Northern Hill region of Chhattisgarh

The Agroclimatic zone II - Northen Hill region of Chhattisgarh covers six districts namely Anuppur, Dindori, Mandla, Shahdol, Singrauli and Umaria. It comes under Rice zone having red and yellow medium black and skeletal (Medium/light) soils. The zone has total geographical area of 3750143 ha, out of which forest area is 42.5% and Mandla is the main contributor as it occupies 7.2 % of total forest area of the ACZ II. Another three districts Shahdol, Singrauli and Umaria contributes to 44.2 % of total zonal forest area. Net area sown is 32.8 % of geographical area, where Umaria is the least contributor (8.5 %). Out of total cropped area of 1698737 ha, the fallow land including current fallow is 1.7%. District wise land utilization is presented in Table 5.

Rainfall analysis

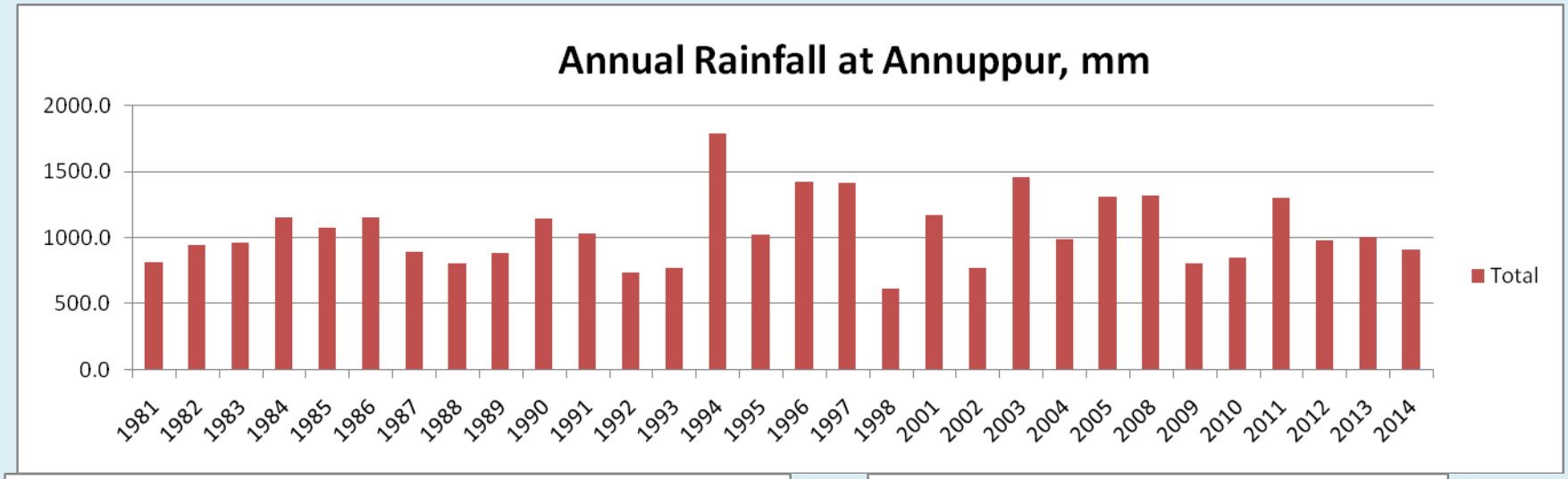
Annual normal rainfall ranges from 1175 to 1445 mm. On an average 89 % of this rainfall occurs during monsoon i.e. June to September, 8% in winter i.e. late December and 2 % in summer. Maximum rainfall occurs in the month of August. The patterns of annual rainfall occurred in different districts of Agroclimatic zone II for years 1970 to 2014 are presented through Figures 8A- 8F. Annual normal rainfall of these districts are 1235.6 mm, 1376.7 mm, 1445.1 mm, 1226.0 mm, 1175.6 mm and 1374.7 mm respectively for Anuppur, Dindori, Mandla, Shahdol, Singrauli and Umaria districts. The record also shows that maximum ever rainfall of 1982 mm (1990) was occurred in Mandla while annual magnitude of rainfall of more than 1800 mm occurred once (1994) in Dindori thrice in Mandla (1971, 1990, 2013) once in Shahdol (1994) and once in Umaria (1994). Respectively for these districts, the annual rainfall exceeded the normal annual rainfall by 21%, 35%, 38%, 23%, 18% and 18%.

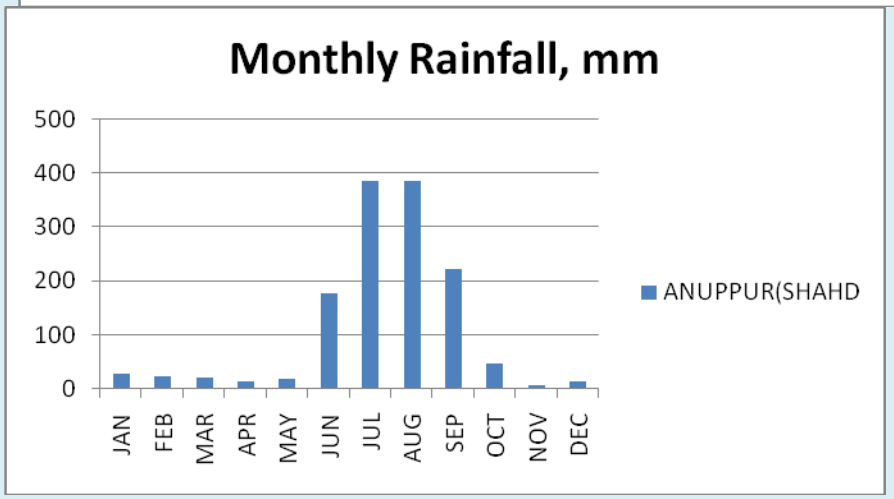
Domestic and livestock water needs

Total population of the zone is 5393961 as per Census 2011. Total human water needs of the zone is 26579 ha m where the maximum consumption is of Singrauli district (5805) followed by Shahdol (5248) and Mandla (5191) districts. Umaria district has minimum water needs of only 3171 ha m. Table 6 illustrates water requirement towards human needs as well as for live stock. Live stock population comprises of cattle both cross breed and indigenous, buffalo, bovine, sheep, goat, horses and ponies, mules, donkey, pigs, dogs, rabbits, fowls, ducks, turkey and other poultry.

Table 5 Total Area and Classification of Area In Each District Northern Hill Region of Chhattisgarh of MADHYAPRADESH State for the year ending 2013- 14															
DISTRICT NAME	Reporting Area For Land Utilization Statics			Not Available For Cultivation			Other Uncultivated Land Excluding Fallow Land			Fallow Land		Total	Net Area Sown	Total Cropped Area	Area Sown more than once
		Forests	Area Under Non Agricultural Uses	Barren and Unculturable Land	Total	Permanent Pastures and Other Grazing Lands	Land Under Misc Tree crops and Groves not Included in Net Area	Culturable Waste Land	Total	Fallow Lands Other than Current Fallows	Current Fallows				
(1)	(2)	(3)	(4)	(5)	6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
ANUPPUR	374671	76448	35013	25568	60581	7782	552	18847	27181	23634	21675	45309	165152	208903	43751
DINDORI	358935	25399	28188	11091	39279	13174	16	16561	29751	28178	33198	61376	203130	289458	86328
MANDLA	965559	593139	43772	10748	54520	20075	71	21241	41387	26286	23067	49353	227160	325097	97937
SHAHDOL	561006	227886	50919	8634	59553	8912	679	38814	48405	22099	11074	33173	191989	268682	76693
SIGNRAOLI	567722	239574	51071	13190	64261	12754	4	42516	55274	16886	24666	41552	167061	226864	59803
UMARIYA	450329	236714	35222	8648	43870	14472	161	17721	32354	17706	14820	32526	104865	145193	40328
Total	**3278222**	**1399160**	**244185**	**77879**	**322064**	**77169**	**1483**	**155700**	**234352**	**134789**	**128500**	**263289**	**1059357**	**1464197**	**404840**

Table 6 : Live stock and Human water needs of ACZ II							
	Anuppur	Dindori	Mandla	Shahdol	Singrauli	Umaria	Zone Total
Cross breed Cattle	7572	506	7603	6131	2850	974	25636
Water Req. (l/day)	1135800	75900	1140450	919650	427500	146100	3845400
Indigenous Cattle	339929	375053	386045	500752	542021	337852	2481652
Water Req. (l/day)	33992900	37505300	38604500	50075200	54202100	33785200	248165200
Buffalo	62058	43204	54641	86900	80167	46335	373305
Water Req. (l/day)	9308700	6480600	8196150	13035000	12025050	6950250	55995750
Bovine	409559	418763	448289	593783	625038	385161	2880593
Water Req. (l/day)	61433850	62814450	67243350	89067450	93755700	57774150	432088950
Sheep	185	73	132	5842	7306	2877	16415
Water Req. (l/day)	1850	730	1320	58420	73060	28770	164150
Goat	64172	65329	77995	104921	231458	68981	612856
Water Req. (l/day)	641720	653290	779950	1049210	2314580	689810	6128560
Horse & Ponies	1098	916	274	249	3	26	2566
Water Req. (l/day)	35685	29770	8905	8092.5	97.5	845	83395
Mules	0	1	447	33	0	0	481
Water Req. (l/day)	0	32.5	14527.5	1072.5	0	0	15632.5
Donkey	35	353	39	23	0	10	460
Water Req. (l/day)	1137.5	11472.5	1267.5	747.5	0	325	14950
Camels	12	87	0	0	0	0	99
Water Req. (l/day)	1380	10005	0	0	0	0	11385
Pigs	3010	5212	3842	5062	3119	1000	21245
Water Req. (l/day)	30100	52120	38420	50620	31190	10000	212450
Dogs	6401	3999	2722	10598	7993	4665	36378
Water Req. (l/day)	32005	19995	13610	52990	39965	23325	181890
Rabbits	154	69	75	115	72	19	504
Water Req. (l/day)	98.56	44.16	48	73.6	46.08	12.16	322.56
Elephants	1	31	22	0	22	0	76
Water Req. (l/day)	150	4650	3300	0	3300	0	11400
Fowls	90695	135825	122185	150236	157783	62568	719292
Water Req. (l/day)	22673.75	33956.25	30546.25	37559	39445.75	15642	179823
Ducks	27	230	106	35	2491	0	2889
Water Req. (l/day)	6.75	57.5	26.5	8.75	622.75	0	722.25
Turkeys	0	0	0	0	0	0	0
Water Req. (l/day)	0	0	0	0	0	0	0
Other Poultry	0	115	0	0	39	0	154
Water Req. (l/day)	0	28.75	0	0	9.75	0	38.5
TWR lpd	107622965	108742168	117180788	155820774	164573029	100334897	754274620
TWR ha m	3892	3931	4237	5634	5946	3629	27269
Human Population	749521	704218	1053522	1064989	1178132	643579	5393961
TWR human, ha m	3693	3470	5191	5248	5805	3171	26579





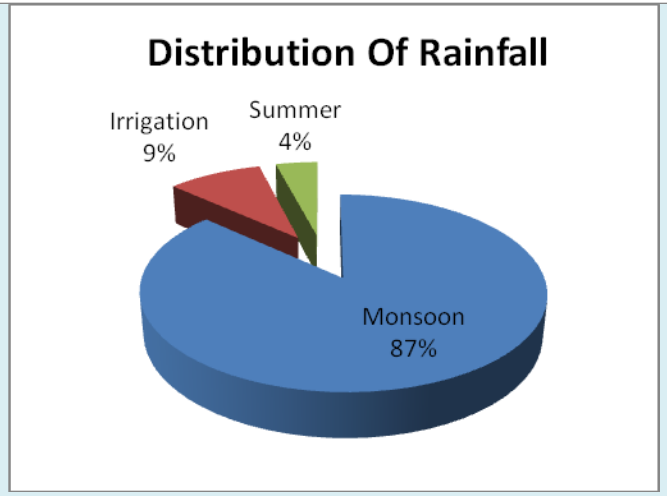
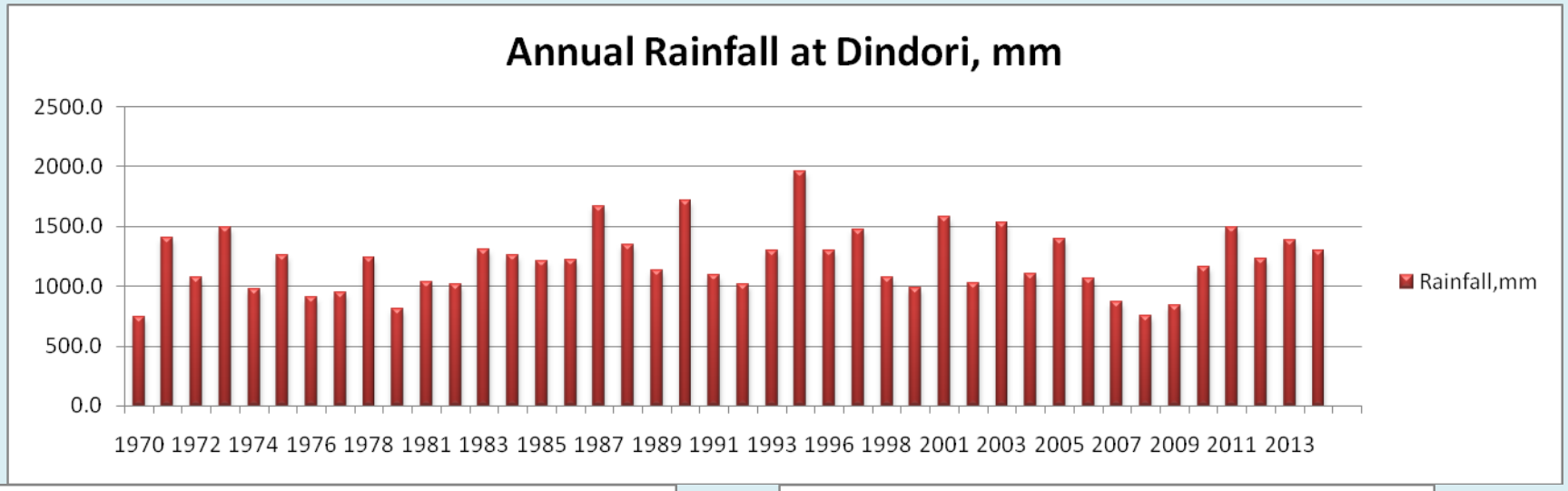
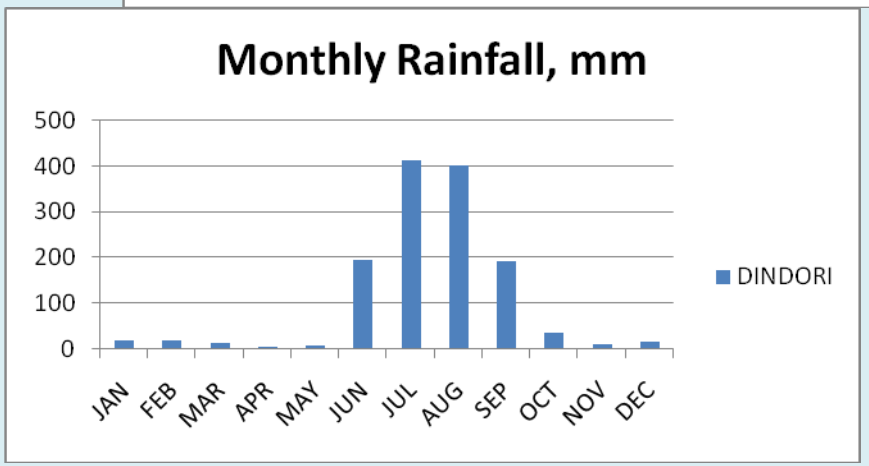


Fig. 8A Rainfall analysis at district Anuppur, Agro-Climatic Zone – II Northern Hill region of Chhattisgarh





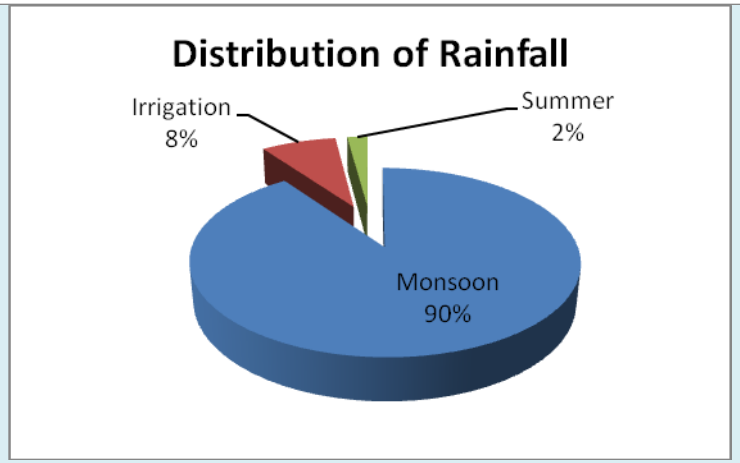
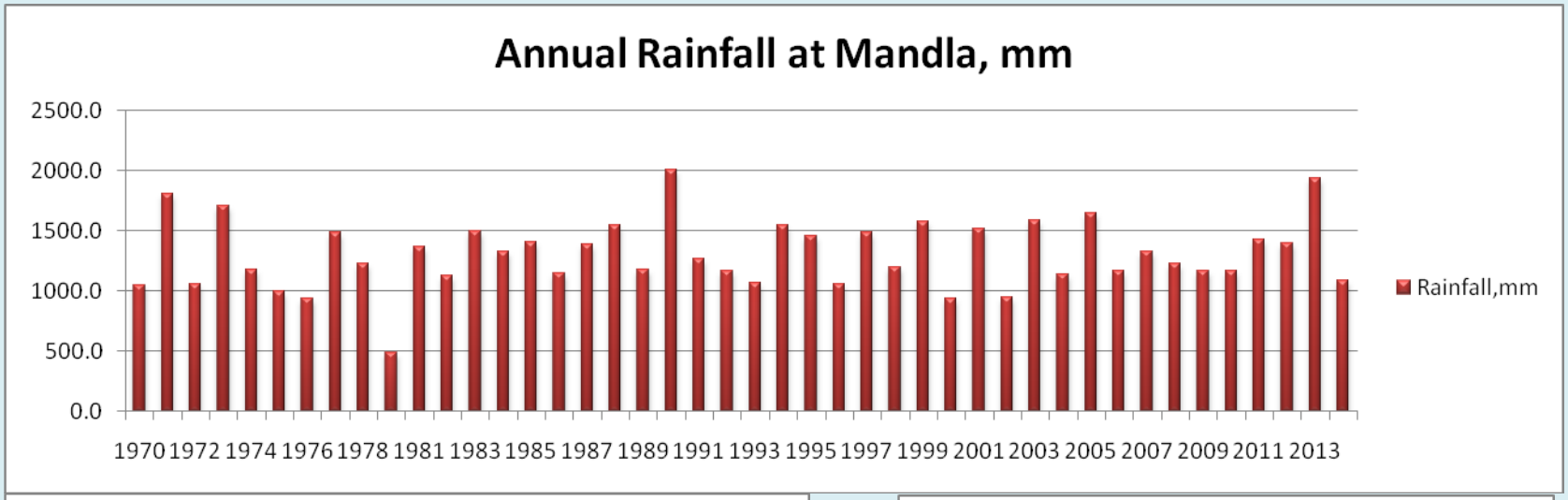
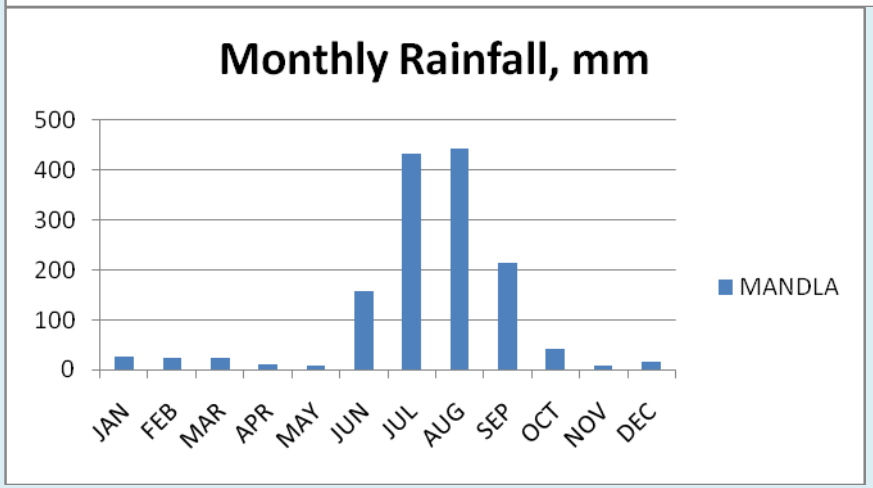


Fig. 8B Rainfall analysis at district Dindori, Agro-Climatic Zone – II Northern Hill region of Chhattisgarh





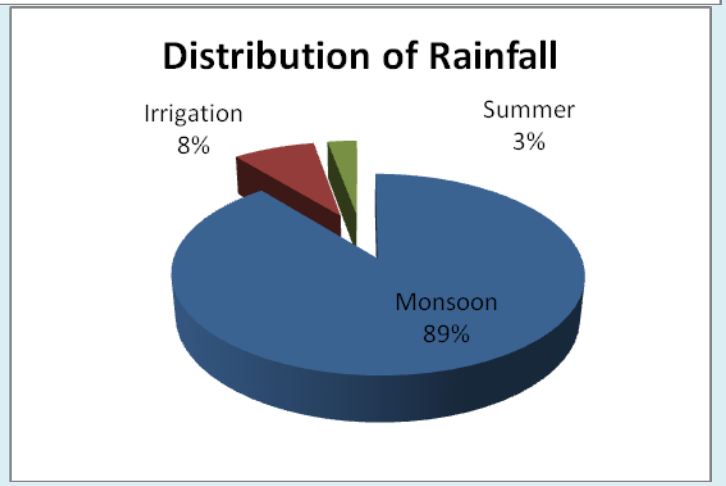


Fig. 8C Rainfall analysis at district Mandla, Agro-Climatic Zone – II, Northern Hill region of Chhattisgarh

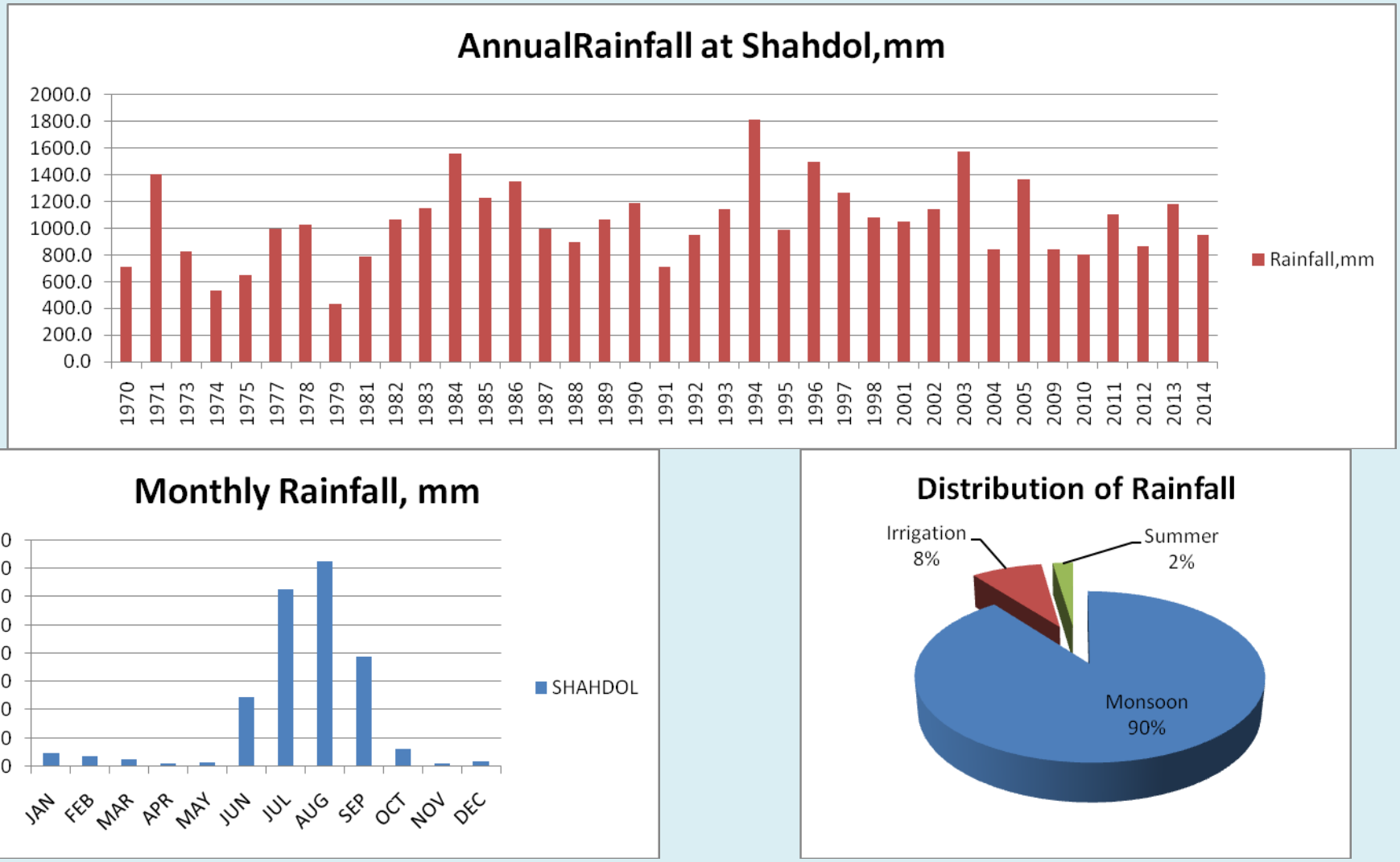


Fig. 8D Rainfall analysis at district Shahdol, Agro-Climatic Zone – II, Northern Hill region of Chhattisgarh

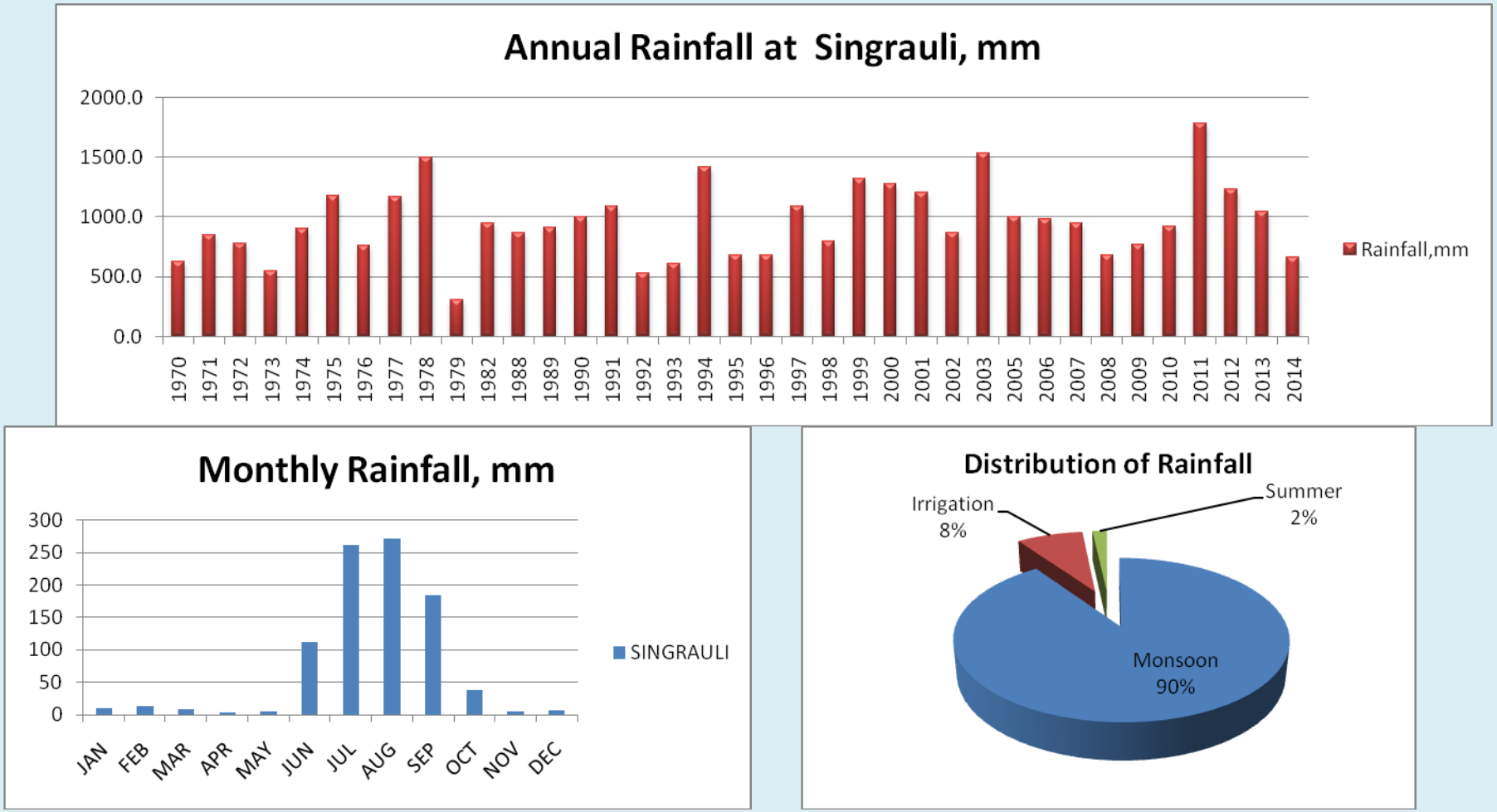
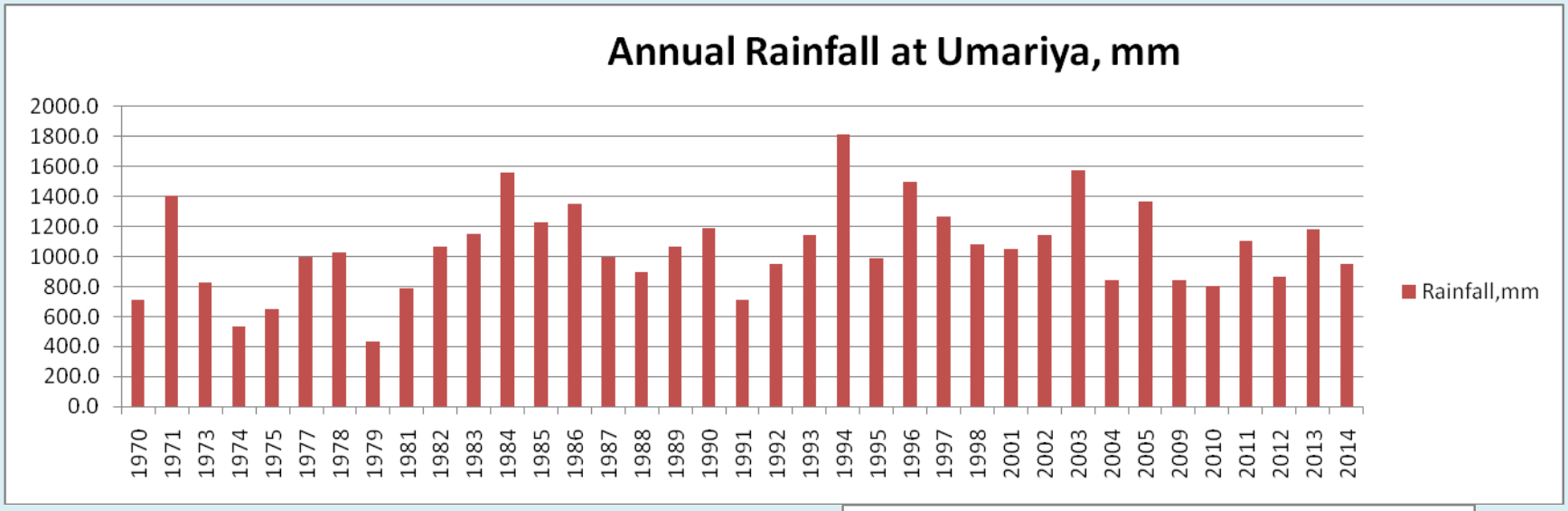
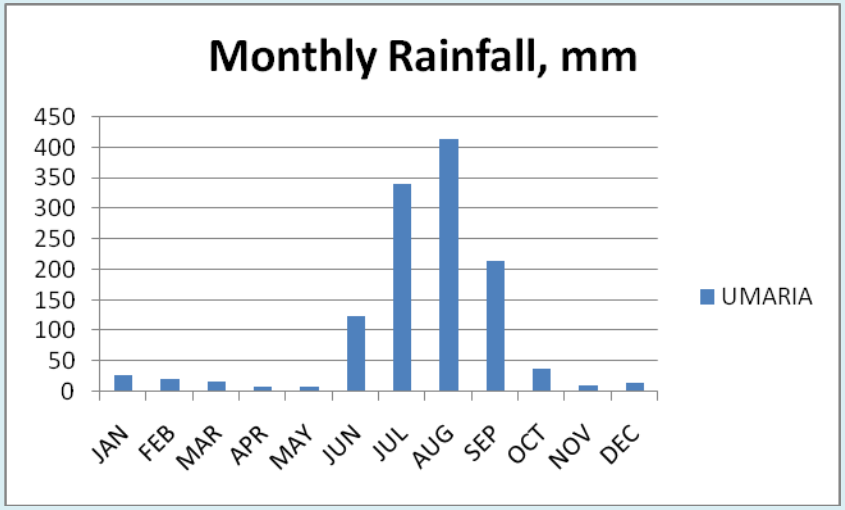


Fig. 8E Rainfall analysis at district Singrauli, Agro-Climatic Zone – II, Northern Hill region of Chhattisgarh





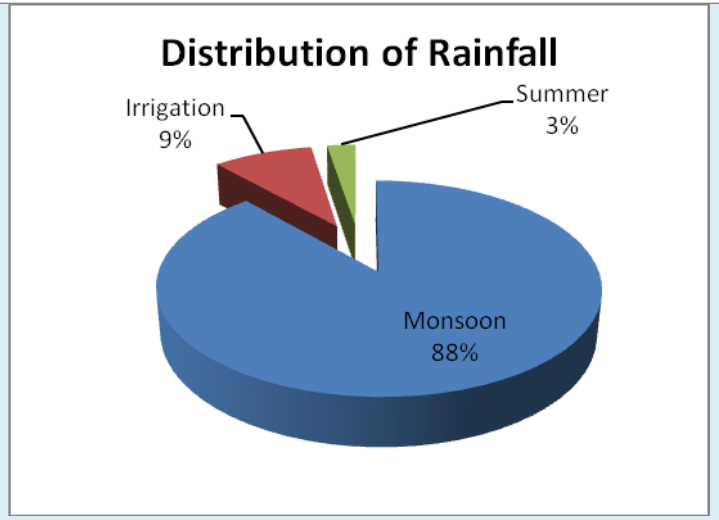


Fig. 8F Rainfall analysis at district Umaria, Agro-Climatic Zone – II, Northern Hill region of Chhattisgarh

Total live stock population of the ACZ II is 754274620. The indigenous cattles are about 96 times more than the cross breed cattle and Anuppur district has maximum percentage (2.2%) of cross breed cattle followed by Mandla and Shahdol. This indicates that the zone has tremendous scope for breeding improvement programmes. The population of buffaloes is maximum in Shahdol (86900) followed by Singrauli (80167) and Anuppur (62058). The bovine is another animal type which found in plenty in this zone aggregating 2880593. Shahdol and Singrauli is the main contributor to this population but other districts are not much behind. The sheep is mostly populated in Singrauli district which also has maximum number (231458) of Goats. Other common animal of the zone is Fowls (719292), dogs (36378) and pigs (21245). Fowls are mostly populated in Shahdol and Singrauli district. The zone has only numeric numbers of animals like rabbits, mules camels, horses and donkeys.

Water requirement of crops

The zone is a Rice zone has 517394 ha under rice. Other major crops are gram (58817 ha), soybean (36338 ha), Pigeon pea (56511 ha), rapeseed and mustard (62215 ha) and maize (93978 ha). Apart from this other pulses (rabi) are also taken in 94269 ha and in Kharif it occupies 74562 ha. Based on growing period, crop coefficient values, the water requirement of all the crops were worked out and presented in Table 7A. Total yearly water requirement of the crops of the zone is 480230 ha m. The major user of water, in terms of crop water requirement is Mandla district (23.6%) followed by Shahdol (19.2%), Dindori (17.6%), Singrauli (14.4%) and Anuppur (14.2%). And due to less cropped area, Umaria required the least water towards crop of 52374 ha-m i.e. 10.9% of zonal crop water requirement. Rice and wheat are the major water users. Figure 9-11 depicts crop water requirement of major crops in the districts of the zone.

Water budget

The agroclimatic zone II (ACZ II)- Northern Hill region of Chhattisgarh receives total quantum of water towards rainfall as 4326701 ha-m. Maximum (32.2 %) of it receives in district Mandla followed by Shahdol (15.9 %), Singrauli (15.4 %) and Umaria (14.3 %).

Table 7 A : Water requirement of field crops in Northern Hill region of Chhattisgarh								
Crops	Anuppur		Dindori		Mandla		Umaria	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Rice	105066	75753	81182	58370	131499	94548	40317	29069
Jowar (Kharif)	244	110	77	35	77	35	404	182
Jowar (Rabi)	-	-	-	-	-	-	-	-
Bajra	-	-	-	-	-	-	-	-
Maize	11342	5592	18314	9107	18526	9212	9236	4553
Ragi	-	-	-	-	-	-	-	-
Wheat	13770	8189	32144	19141	42687	25419	30903	18379
Barley	59	33	14	8	11	6	324	184
Other Cereals and Millets (Kharif)	12613	5911	38274	17887	28301	13226	10073	4721
Other Cereals and Millets (Rabi)	-	-	-	-	42	22	-	-
Gram	4624	2531	9409	5157	9652	5290	7251	3969
Arhar (Tur)	5612	3233	5567	3215	6128	3539	9162	5279
Other Pulses (Rabi)	21537	11062	3785	1946	49134	25268	7939	4078
Other Pulses (Kharif)	2830	1285	48585	22008	2105	954	3348	1521
Sugarcane	19	24	3	4	3194	4137	4	5
Groundnut	556	282	16	8	2	1	17	9
Castor seed	-	-	-	-	-	-	-	-
Sesamum	1097	534	407	198	1383	671	3738	1819
Rapeseed and Mustard	8445	4383	16797	8680	15995	8265	6911	3587
Linseed	4422	2421	5029	2756	5584	3061	3009	1647
Soyabean	5843	2203	7224	2747	1896	721	9471	3571
Niger seed	8020	5583	21782	15089	5832	4040	1199	835
Sunflower	-	-	-	-	-	-	-	-
Safflower	-	-	-	-	-	-	-	-
Other Oilseeds	-	-	-	-	-	-	6	3
Cotton	-	-	-	-	-	-	-	-
Jute	-	-	-	-	-	-	-	-
Mesta	-	-	-	-	-	-	-	-
Sanhemp	41	32	15	12	190	150	-	-
Other Fibres	-	-	-	-	7	5	-	-

Table 7B : Water requirement of fruits and vegetables crops in Northern Hill region of Chhattisgarh, ha m								
	Anuppur		Dindori		Mandla		Umaria	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Chillies	139	149	11	12	77	82	93	100
Ginger	257	302	-	-	18	21	88	104
Turmeric	5	6	-	-	2	2	60	70
Betel nut	-	-	-	-	-	-	-	-
Garlic	64	101	2	3	16	25	56	88
Coriander	124	172	231	323	388	542	58	81
Other Condiments and Spices	31	38	-	-	3	4	8	10
Mango	117	184	-	-	28	44	6	9
Banana	1	2	-	-	-	-	-	-
Citrus Fruits	-	-	-	-	1	1	-	-
Grapes	-	-	-	-	-	-	-	-
Papaya	-	-	-	-	-	-	-	-
Other Fruits	14	22	10	16	56	88	2	3
Potato	327	300	17	16	289	264	538	494
Sweet Potato	84	55	8	5	58	38	129	84
Onion	167	278	76	127	368	615	215	358
Other Vegetables (Kharif)	519	337	23	15	379	245	204	132
Other Vegetables (Rabi)	903	659	406	297	1167	853	424	309
Opium	-	-	-	-	-	-	-	-
Tobacco	2	1	-	-	-	-	-	-
Other Plantation Crops	-	-	-	-	1	2	-	-
Fodder Crops	9	6	-	-	1	1	-	-
Other Non Food Crops	-	-	50	63	-	-	-	-

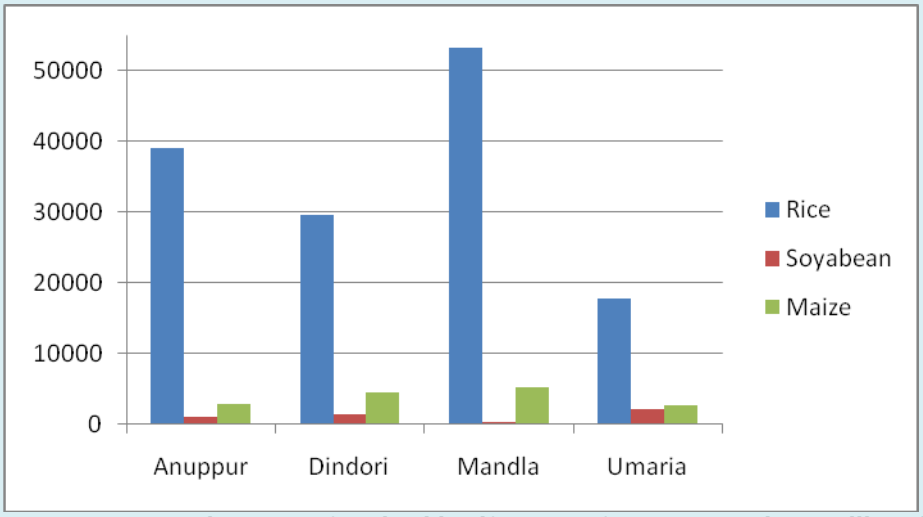


Fig. 9 Crop water requirement of major kharif crops of ACZ II -Northern Hill region of Chhattisgarh in ha m

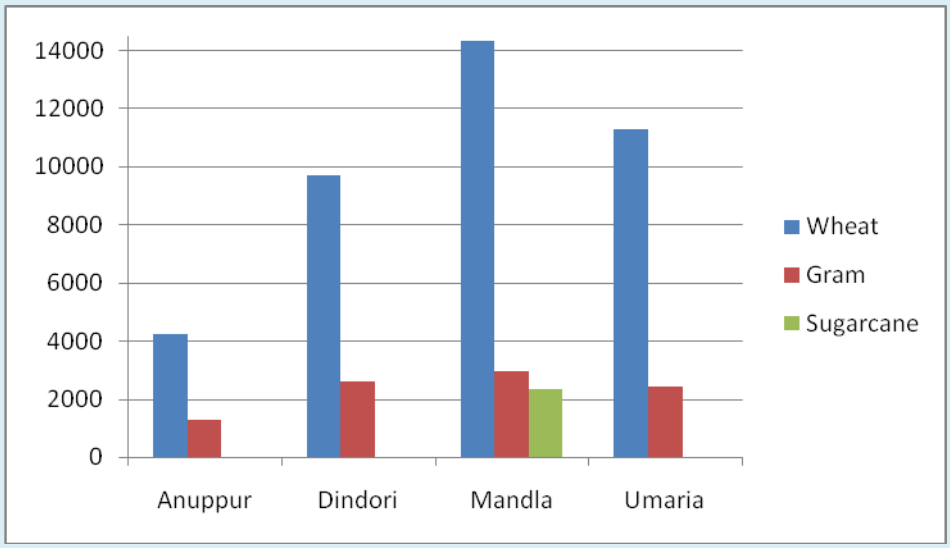


Fig.10 Crop water requirement of major rabi crops of ACZ II -Northern Hill region of Chhattisgarh in ha m

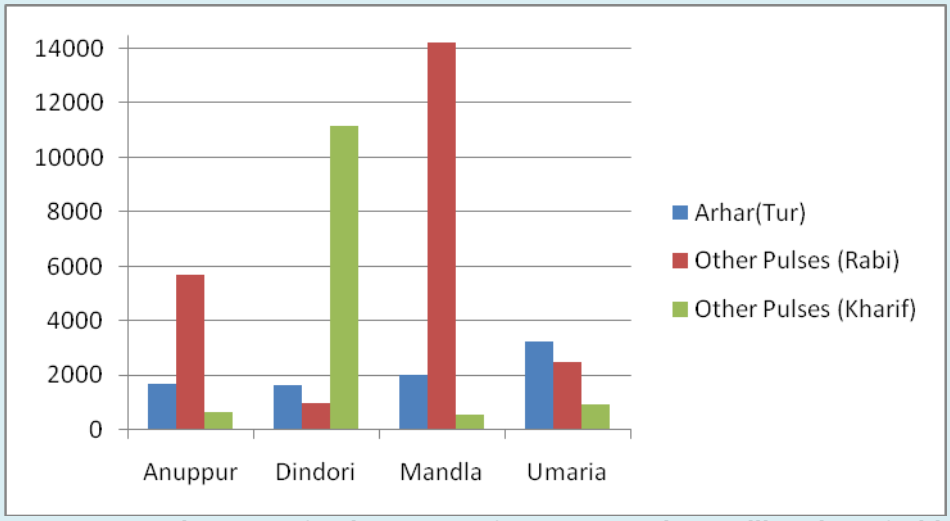


Fig. 11 Crop water requirement of pulse crops of ACZ II - Northern Hill region of Chhattisgarh in ha m

The least water as rainfall receives in Anuppur district which is 10.7 % of zonal total. National Commission on Agriculture has laid down norms for water budgeting of an area and as per its estimate the losses of water as evaporation, surface water flow and ground water flow out of the area is calculated in present estimation. Similarly, addition of water into the area as runoff generated from the zone, addition of soil moisture and to the ground water is also computed. The water budget so generated for ACZ II is presented in Table 8. The immediate evaporation loss that occurs during the rainfall is taken as 17.5% of total rainfall and it is 757173 ha-m for the zone. 28.7% rainfall converts into surface flow and it is 1241763 ha-m. It is considered that 10.549% (206294 ha-m) of surface flow goes out of the zone. Ground water also adds to the surface flow and it is taken as 23.739% of surface flow. Thus, surface flow arrives to be 1955582 ha-m which is 45.198% of total precipitation.

Evaporation takes place from open water body, soil surface, forest and vegetation and also from rise of water table, and, respectively it is taken as 7.916% (154804 ha-m) of total surface flow 31.504% (606504 ha-m) of total soil moisture storage, 30.826% (593452 ha-m) of total soil moisture and 18.451% (171575 ha-m) of total ground water. Part of rainfall as recharge enriches ground water and it is 12.5 % (540838 ha-m). There is an addition to the ground water from streams and flood flows which is -4.851 % (-94865 ha-m) of total surface flow. The total utilizable surface and ground water for the ACZ- II computed as 1245255 ha-m.
The soil moisture increases due to rainfall as well as from irrigation. 41.3% of rainfall and 7.067% of total surface flow is considered as soil moisture storage. Total zonal soil moisture storage is 1786928 ha-m and out of this 725268 ha-m is available as ET for the crops. Each and every district of the ACZ II zone contributes in same proportion in zonal water budgeting as the quantum of rainfall of each district contributes in zonal rainfall quantum owing to rainfall based water distribution.

Utilization of water takes place in four major categories. These are domestic and animal water needs, crop water requirement and requirement of water for industrial and recreation. Water needs of different sectors in districts of ACZ II is presented in Fig. 12. Total crop water requirement of the zone is 480231 ha-m and out of which Mandla needs maximum water towards crops as each has 23.6 % of zonal total.

Table 8 Water budgeting of Northern hill region of Chhattisgarh , ha-m

S.N	Particulars	Anuppur	Dindori	Mandla	Shahdol	Singrauli	Umaria	Zone Total
1	Normal rainfall, ha-m	462943	494145	1395339	687793	667414	619067	4326701
2	Immediate evaporation (17.5%)	81015	86475	244184	120364	116797	108337	757173
3	Surface flow (28.7%)	132865	141820	400462	197397	191548	177672	1241763
4	From outside state(10.549% of total surface flow)	22073	23561	66529	32794	31822	29517	206294
5	To GW from flood flows (-4.851% of total surface flow)	-10150	-10834	-30594	-15080	-14633	-13573	-94865
6	From GW to surface flow(23.739% of total surface flow)	49672	53020	149714	73797	71611	66423	464236
7	From irrigated area to surface flow(7.067% of total surface flow)	14787	15784	44569	21969	21318	19774	138201
8	Total surface flow(45.198% of total ppt)	209241	223344	630665	310869	301658	279806	1955582
9	Evaporation losses from reservoirs and tanks (7.916% of total surface flow)	16564	17680	49923	24608	23879	22149	154804
10	Flow into seas and outside state (43.445% of total surface flow)	90905	97032	273993	135057	131055	121562	849603
11	Utilizable surface flow (48.639% of total surface flow)	101773	108632	306749	151203	146723	136095	951176
12	Water available for ground water storage (12.5%)	57868	61768	174417	85974	83427	77383	540838
13	From streams and flood flows to GW(4.851% of total surface flow)	10150	10834	30594	15080	14633	13573	94865
14	From irrigation to GW addition (S.N.15-(12+13))	31478	33599	94875	46766	45380	42093	294192
15	Total GW (21.492% of total ppt)	99496	106202	299886	147820	143441	133050	929895
16	Evaporation and rise of water table (18.451% of total GW)	18358	19595	55332	27274	26466	24549	171575
17	Regeneration into streams(49.924% of total GW)	49672	53020	149715	73798	71611	66424	464241

18	GW available utilization(31.625% of total GW)	31466	33586	94839	46748	45363	42077	294079
19	Total utilizable surface + GW (S.N. 11+18)	133238	142218	401588	197952	192086	178172	1245255
20	Soil moisture storage (41.3% of normal rainfall)	191195	204082	576275	284059	275642	255675	1786928
21	From irrigated area to soil moisture(7.067% of total surface flow)	14787	15784	44569	21969	21318	19774	138201
22	Total soil moisture storage (44.495% of total ppt)	205986	219870	620856	306033	296966	275454	1925166
23	Evaporation losses from soil moisture (31.504% of total soil moisture storage)	64894	69268	195595	96413	93556	86779	606504
24	Evap. losses from forest and other veg. (30.826% of total soil moisture)	63497	67777	191385	94338	91543	84911	593452
25	Soil moisture available for ET from crops (37.673 % of total soil moisture)	77601	82832	233895	115292	111876	103772	725268
26	Water requirement of crops	68014	84671	113537	92253	69382	52374	480231
27	Water requirement of animal husbandry	3892	3931	4237	5634	5946	3629	27269
28	Domestic water requirement	3693	3470	5191	5149	5805	3171	26479
29	Industrial Water requirement @ 6 % of available fresh water	24197	22950	45373	38601	29242	24637	185000
30	Water available for utilization (S.N. 19+25)	210840	225050	635483	313244	303962	281944	1970522
31	Water required for different sectors (26+27+28+29)	99796	115022	168338	141637	110375	83811	718979
32	Surplus or deficit of water in the district (30-31)	111044	110028	467145	171607	193587	198133	1251543

The least crop water demand comes from Umaria district (10.9 %). In comparison to the crop water demand the water demand towards domestic and animal husbandry is very low as it is respectively 26479 ha m and 27269 ha-m. Owing to more population in Singrauli, Mandla and Shahdol, the domestic demand is about 61 % of the zonal demand. Umaria registers the least domestic water demand i.e. only

12%. The Singrauli and Shahdol districts have more animal husbandry and demand for 42 % of the zonal animal water needs of it. The industrial demand is computed as 6% of available water thus total zonal demand comes out as 185000 ha-m. Total water needs and supply of different districts of ACZ II is presented in Fig. 13. The excess of water is also shown in the figure. The water available for utilization at zonal level is 1970522 ha-m. The maximum share (32.2 %) is available at Mandla district followed by Shahdol (15.8%) and Singrauli (15.4 %). The total zonal water demand is 718979 ha-m and Mandla district requires the maximum share of 23.4 % followed by Shahdol (19.6 %) and Dindori (15.9%). The Umaria district requires the least water i.e. 11.6 % of the zonal total. As for as the excess water concerns the zone has 1251543 ha-m of surplus water and maximum of it lies in Mandla District (37.3 %) followed by Umaria (15.8 %) and Singrauli (15.5 %). The least share of 8.8 % is available as surplus water in Dindori district. An abstract in pictorial form is provided in Fig 14.

Interestingly, Districts Anuppur (17.8 %), Dindori (22.3 %), Shahdol (18.1 %)) and Singrauli (17.5 %) requires more water than the zonal share of availability which is respectively 10.7 % , 11.4 %, 15.9 % and 15.4 % for these districts. But when within the district demand supply is taken into account it was found out that districts have 109 %, 90 %, 319 %, 120 %, 129 % and 240% excess water within them. Taking net sown area of these district, as per Directorate of Extension and Farmers Welfare, 165152 ha, 203130 ha, 227160 ha, 191989 ha, 167061 ha and 104865 ha, the per hectare water availability due to this surplus water comes out to be 67 cm, 52 cm, 213 cm, 89 cm, 103 cm and 190 cm. It means, the future plans to enhance crop production or alternate cropping may be based on this much depth of water.

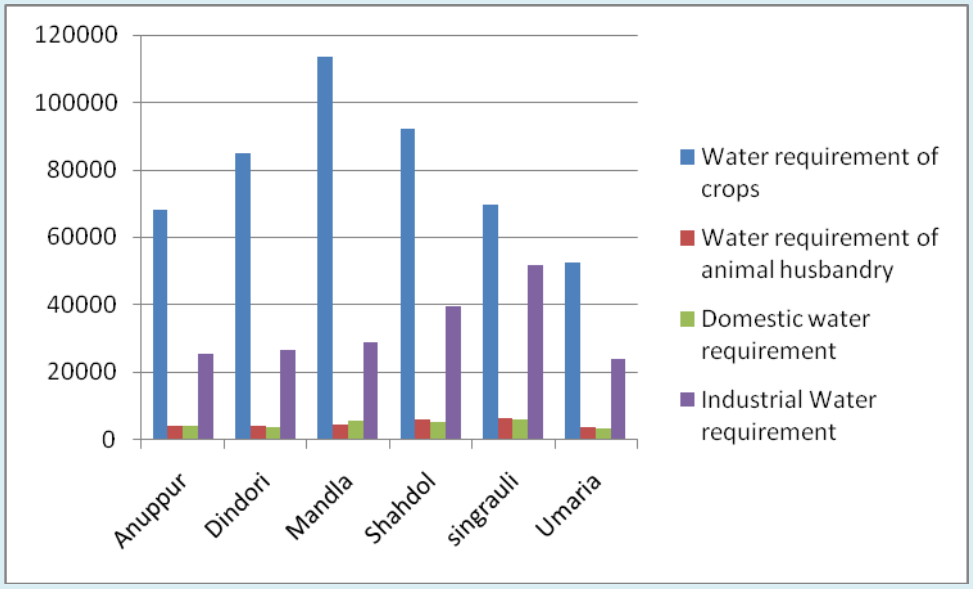


Fig. 12 Water needs of different sectors in districts of ACZ II - Northern Hills of Chhattisgarh (ha-m)

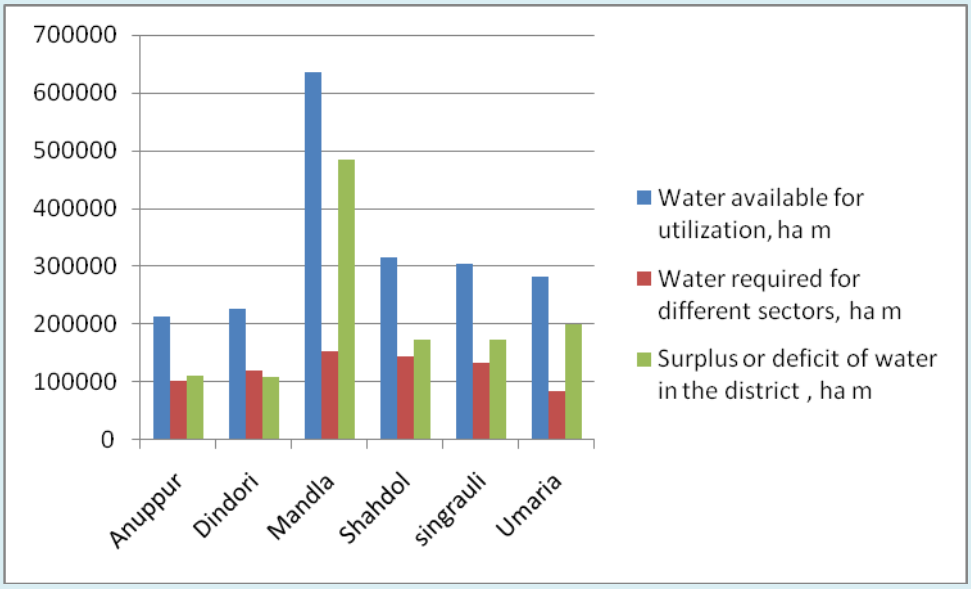


Fig. 13 Total Water needs and supply of different districts of ACZ II - Northern Hills of Chhattisgarh (ha-m)

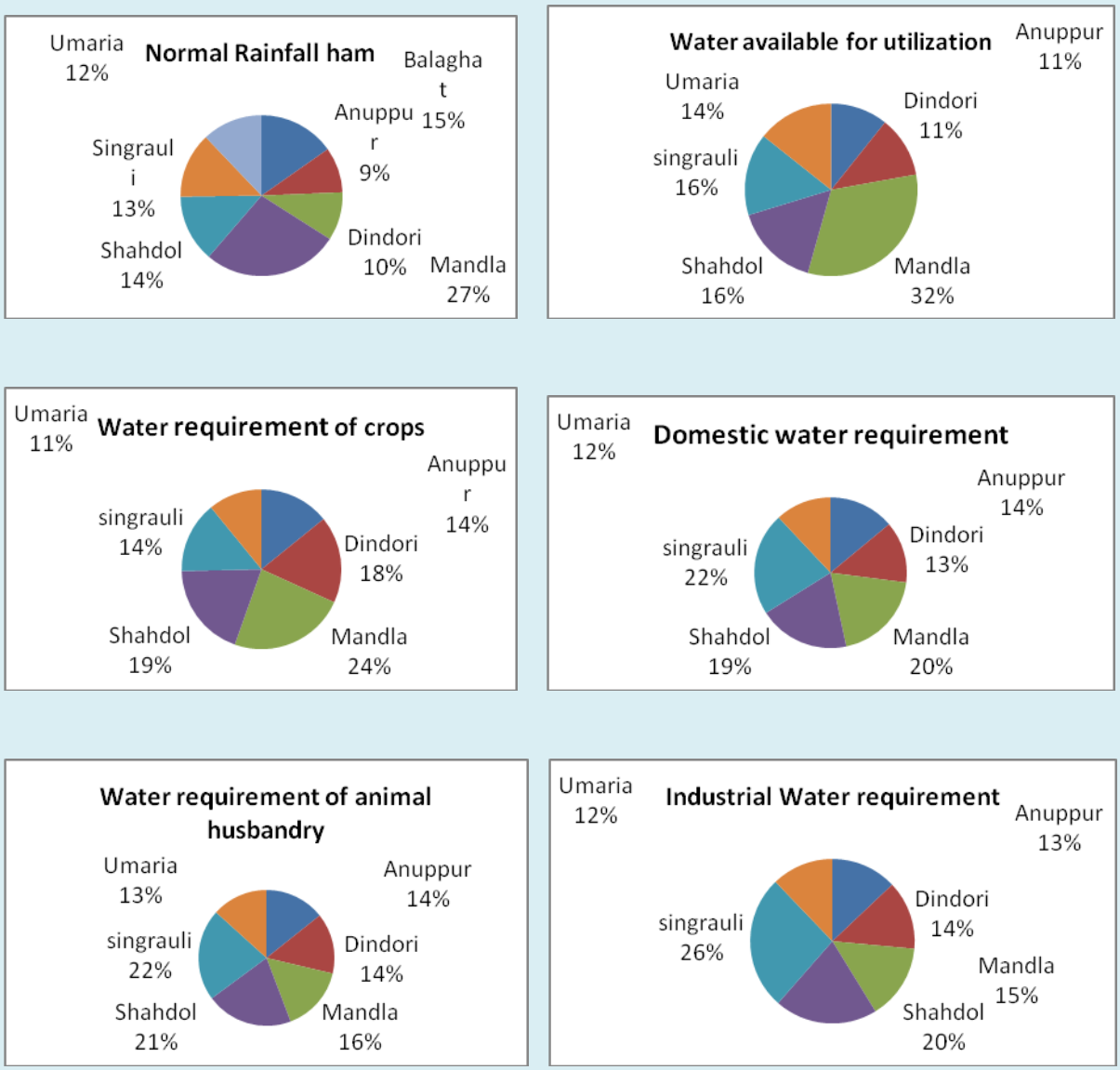


Fig. 14 Abstract of water of different districts of ACZ II - Northern Hills of Chhattisgarh (ha-m)

Agroclimatic Zone III - Kymore Plateau and Satpura Hills

The Agroclimatic zone III - Kymore Plateau and Satpura Hills covers seven districts namely Jabalpur, Katni, Panna , Rewa, Satna, Seoni and Sidhi. It comes under Wheat-rice zone having mixed black (medium) and red soils. The zone has total geographical area of 4434272 ha, out of which forest area is 29% and Panna and Seoni are the main contributors. Net area sown is 46.2% where Sidhi is the least contributor. Out of total Net Sown area of 2049620 ha, the fallow land including current fallow is 10.3%. District wise land utilization is presented in Table 9.

Rainfall analysis

Annual rainfall ranges from 1000 to 1400 mm. On an average 90 % of this rainfall occurs during monsoon i.e. June to September, 8% in winter i.e. late December and 1% in summer. Maximum rainfall occurs in the month of August except in Seoni district where it is in the month of July with average rainfall of 87% in monsoon and 4 % in summer. The patterns of annual rainfall occurred in different districts of Agroclimatic zone III for years 1970 to 2014 are presented through Figures 15 A-G. Mean annual rainfall of these districts are 1227.4mm, 1171.4 mm, 1182.9 mm, 1143.1 mm, 1077.7 mm,1317.6 mm and 1175.6 mm respectively for Jabalpur, Katni, Panna, Rewa, Satna, Seoni and Sidhi districts. The record also shows maximum ever rainfall of 2560 mm (1994) was occurred in Jabalpur while annual magnitude of rainfall of more than 2000 mm occurred once in Katni (2005) and Panna (1982) districts. In the rest of districts of the zone the rainfall never exceeded 1800 mm. Respectively for these districts, the annual rainfall exceeded the normal annual rainfall by 63%, 35%, 57%, 46%, 49%, 40% and 37% .

Domestic and livestock water needs

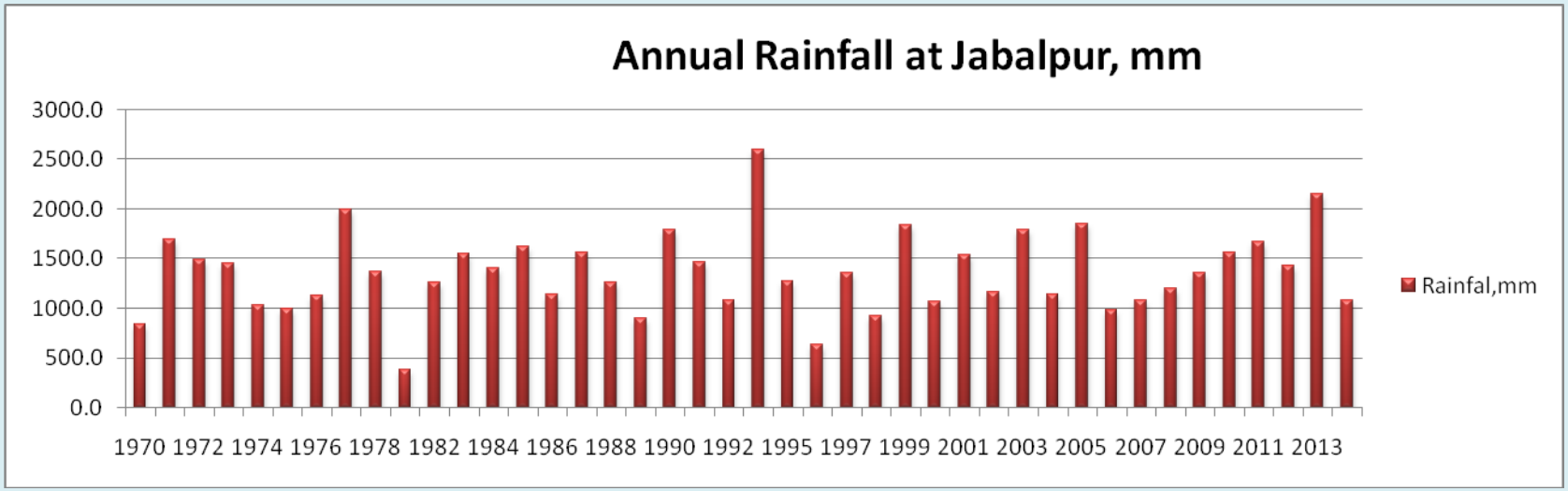
Total population of the zone is 11866180 as per Census 2011. Total human water needs of the zone is 58471 ha m where the maximum consumption is of Jabalpur district (12125) followed by Rewa (11647) and Satna (10982) districts. Panna district has minimum water needs of only 5006 ha m. Table 10 illustrates water requirement towards human needs as well as for live stock. Live stock population comprises of cattle both cross breed and indigenous, buffalo, bovine, sheep, goat, horses and ponnies, mules, donkey, pigs, dogs, rabbits, fowls, ducks, turkey and other poultry.

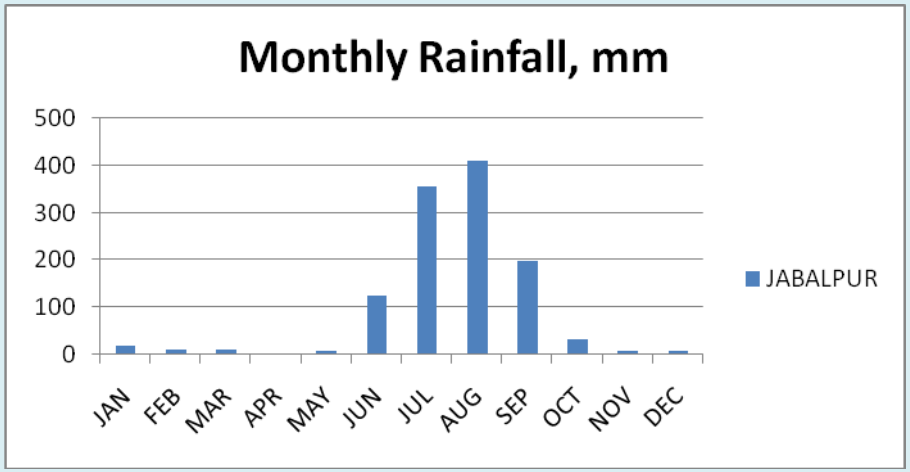
Table 9 Total Area and Classification of Area In Each District of Kymore Plateau and Satpura Hills MADHYAPRADESH State for the year ending 2013- 14															
DISTRICT NAME	Reporting Area For Land Utilization Statics			Not Available For Cultivation			Other Uncultivated Land Excluding Fallow Land			Fallow Land		Total	Net Area Sown	Total Cropped Area	Area Sown more than once
		Forests	Area Under Non Agricultural Uses	Barren and Unculturable Land	Total	Permanent Pastures and Other Grazing Lands	Land Under Misc Tree crops and Groves not Included in Net Area	Culturable Waste Land	Total	Fallow Lands Other than Current Fallows	Current Fallows				
(1)	(2)	(3)	(4)	(5)	6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
JABALPUR	519757	76677	41470	36919	78389	39948	106	24580	64634	12705	8644	21349	278708	424268	145560
KATANI	493092	97122	38181	37141	75322	39544	25	31414	70983	18934	13947	32881	216784	308195	91411
PANNA	702924	299723	43888	22538	66426	11050	50	44790	55840	5364	3614	8978	271957	417540	145583
REWA	628745	85414	63145	32607	95752	25730	2383	6401	34514	26510	23492	50002	363063	517271	154208
SATNA	742432	203736	70211	15346	85557	19605	3471	46867	69943	16601	13821	30422	352774	515188	162414
SEONI	875401	328485	49538	11819	61357	20333	31	30047	50411	19543	18729	38272	396876	578037	181161
SIDHI	471921	195128	37993	3849	41842	5333	1	31277	36611	12594	16288	28882	169458	234540	65082
Total	**4434272**	**1286285**	**344426**	**160219**	**504645**	**161543**	**6017**	**215376**	**382936**	**112251**	**98535**	**210786**	**2049620**	**2995039**	**945419**

Table 10 : Live stock and Human water needs of ACZ III

	Jabalpur	Katni	Panna	Rewa	Satna	Seoni	Sidhi	Zone Total
Cross breed Cattle	27922	3497	1408	41391	23956	21376	14314	133864
Water Req. (l/day)	4188300	524550	211200	6208650	3593400	3206400	2147100	20079600
Indigenous Cattle	337423	431864	413407	872814	829593	491310	433067	3809478
Water Req. (l/day)	33742300	43186400	41340700	87281400	82959300	49131000	43306700	380947800
Buffalo	95324	51866	141895	170806	196178	124943	94039	875051
Water Req. (l/day)	14298600	7779900	21284250	25620900	29426700	18741450	14105850	131257650
Bovine	460669	487227	556710	1085011	1049727	637629	541420	4818393
Water Req. (l/day)	69100350	73084050	83506500	162751650	157459050	95644350	81213000	722758950
Sheep	1170	1522	4011	24120	15178	45	8803	54849
Water Req. (l/day)	11700	15220	40110	241200	151780	450	88030	548490
Goat	104280	92760	125289	198629	252606	172503	190999	1137066
Water Req. (l/day)	1042800	927600	1252890	1986290	2526060	1725030	1909990	11370660
Horse & Ponies	118	59	353	145	288	145	35	1143
Water Req. (l/day)	3835	1917.5	11472.5	4712.5	9360	4712.5	1137.5	37147.5
Mules	1	18	236	73	128	3	42	501
Water Req. (l/day)	32.5	585	7670	2372.5	4160	97.5	1365	16282.5
Donkey	20	10	327	81	122	20	23	603
Water Req. (l/day)	650	325	10627.5	2632.5	3965	650	747.5	19597.5
Camels	0	5	0	0	0	0	0	5
Water Req. (l/day)	0	575	0	0	0	0	0	575
Pigs	4832	3409	6477	15103	9412	3709	12776	55718
Water Req. (l/day)	48320	34090	64770	151030	94120	37090	127760	557180
Dogs	12977	3156	6936	16298	16080	11223	14625	81295
Water Req. (l/day)	64885	15780	34680	81490	80400	56115	73125	406475

	Jabalpur	Katni	Panna	Rewa	Satna	Seoni	Sidhi	Zone Total
Rabbits	42	37	8	139	92	143	359	820
Water Req. (l/day)	26.88	23.68	5.12	88.96	58.88	91.52	229.76	524.8
Elephants	0	0	6	11	0	262	73	352
Water Req. (l/day)	0	0	900	1650	0	39300	10950	52800
Fowls	56114	16519	52350	53801	49821	227696	210950	667251
Water Req. (l/day)	14028.5	4129.75	13087.5	13450.25	12455.25	56924	52737.5	166812.75
Ducks	1054	98	98	525	977	190	41	2983
Water Req. (l/day)	263.5	24.5	24.5	131.25	244.25	47.5	10.25	745.75
Turkeys	2804	106	0	0	0	0	0	2910
Water Req. (l/day)	701	26.5	0	0	0	0	0	727.5
Other Poultry	1873	29	0	0	0	464	0	2366
Water Req. (l/day)	468.25	7.25	0	0	0	116	0	591.5
TWR lpd	123623884	126667386	149088398	286826595	278765211	170335485	144560299	1279867258
TWR ha m	4472	4583	5394	10379	10086	6155	5221	46290
Human Population	2460714	1291684	1016028	2363744	2228619	1378876	1126515	11866180
TWR human, ha-m	12125	6365	5006	11647	10982	6794	5551	58471





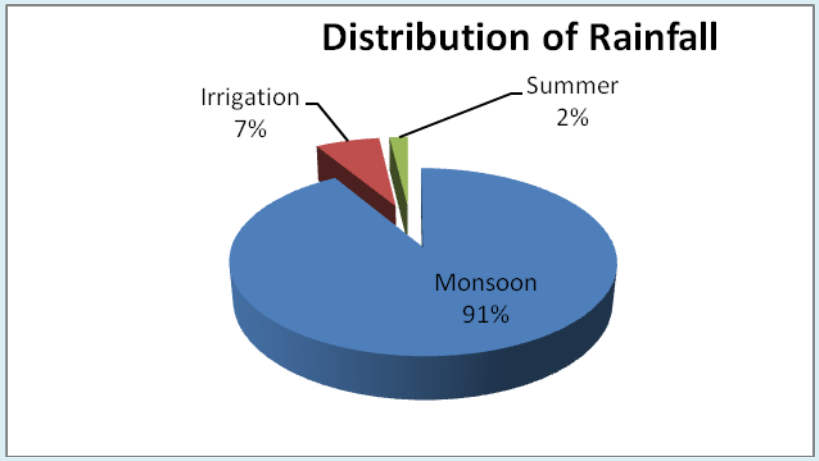
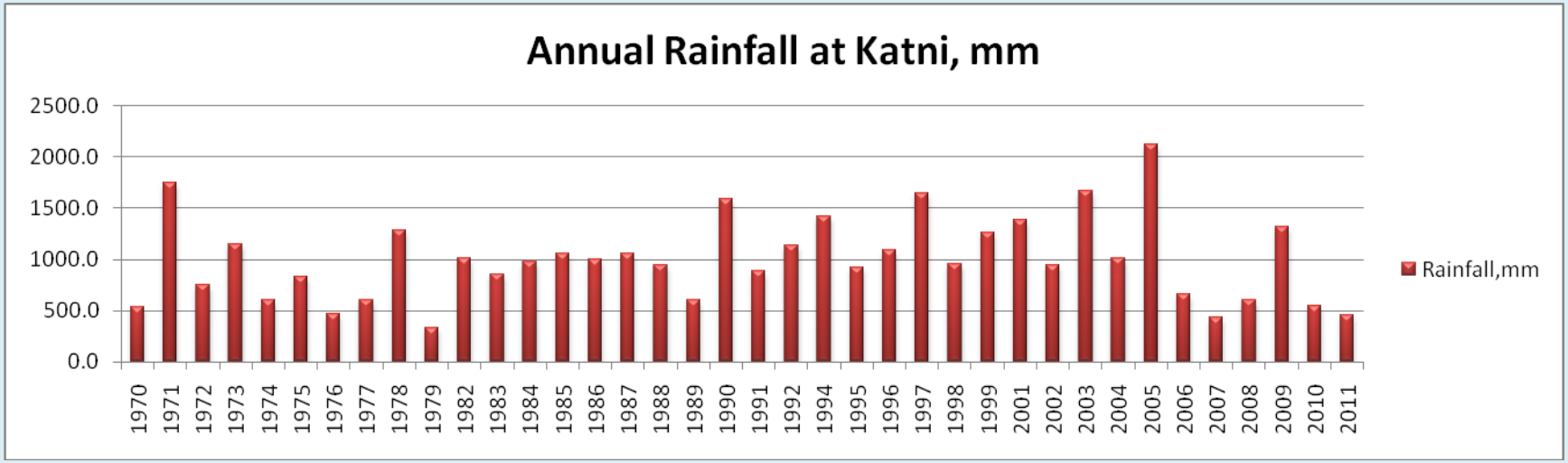
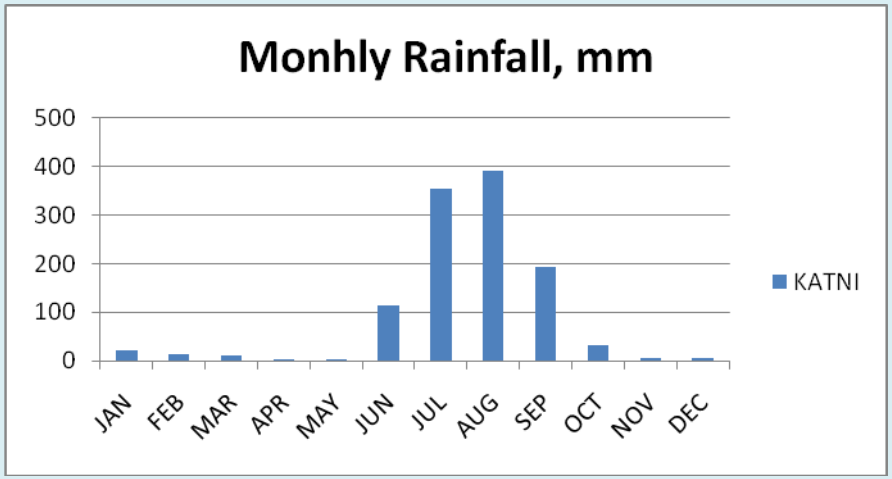


Fig. 15A Rainfall analysis at district Jabalpur, Agro-Climatic Zone – III, Kymore Plateau & Satpura Hills





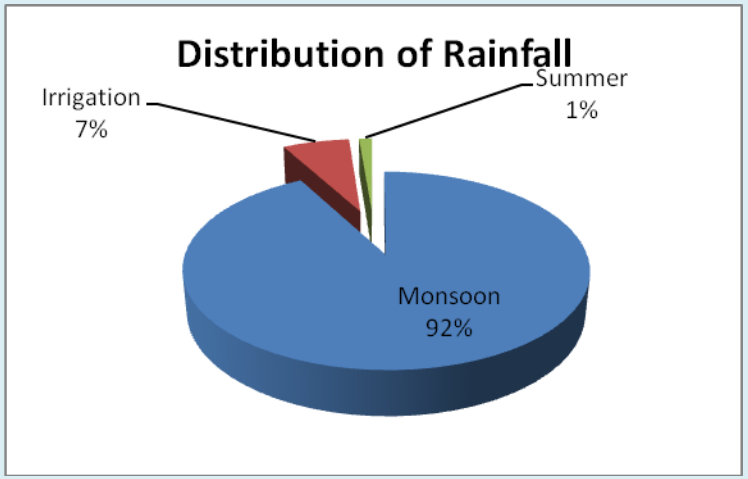
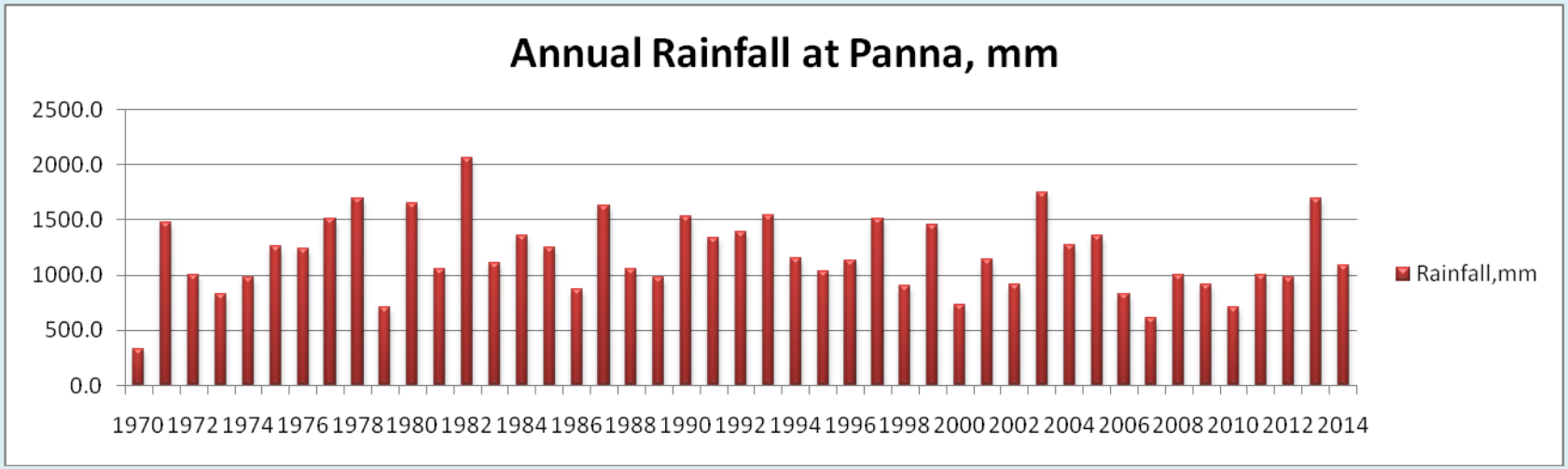
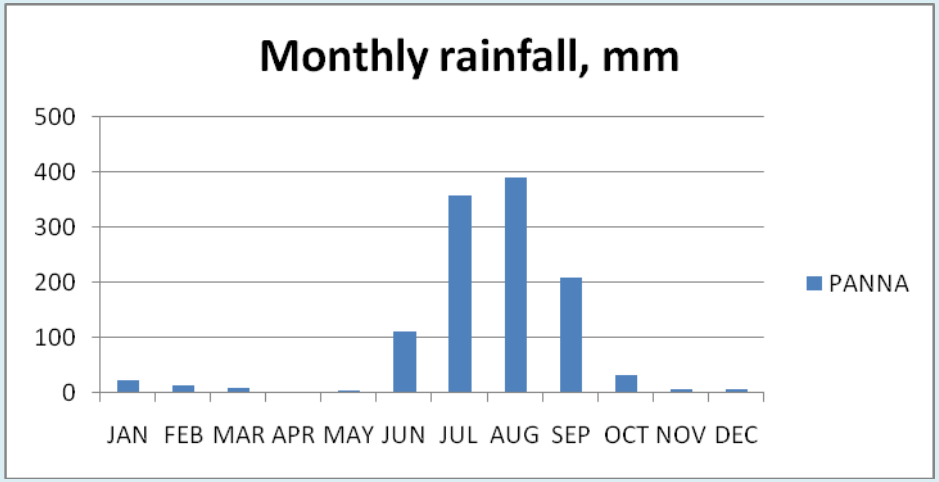


Fig. 15B Rainfall analysis at district Katni, Agro-Climatic Zone – III, Kymore Plateau & Satpura Hills





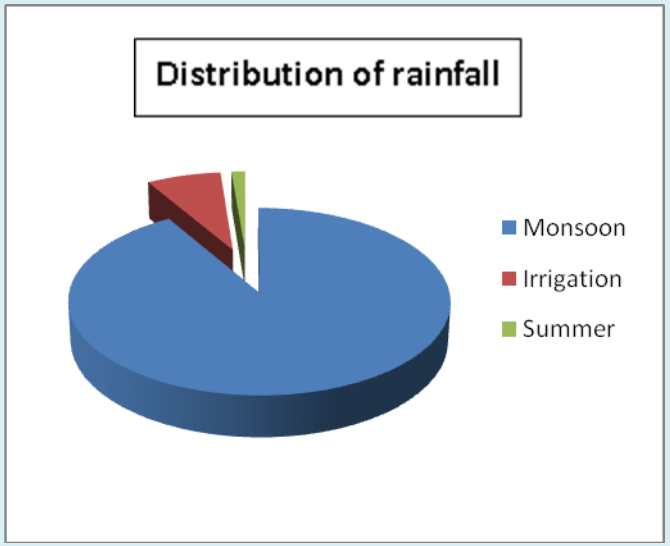
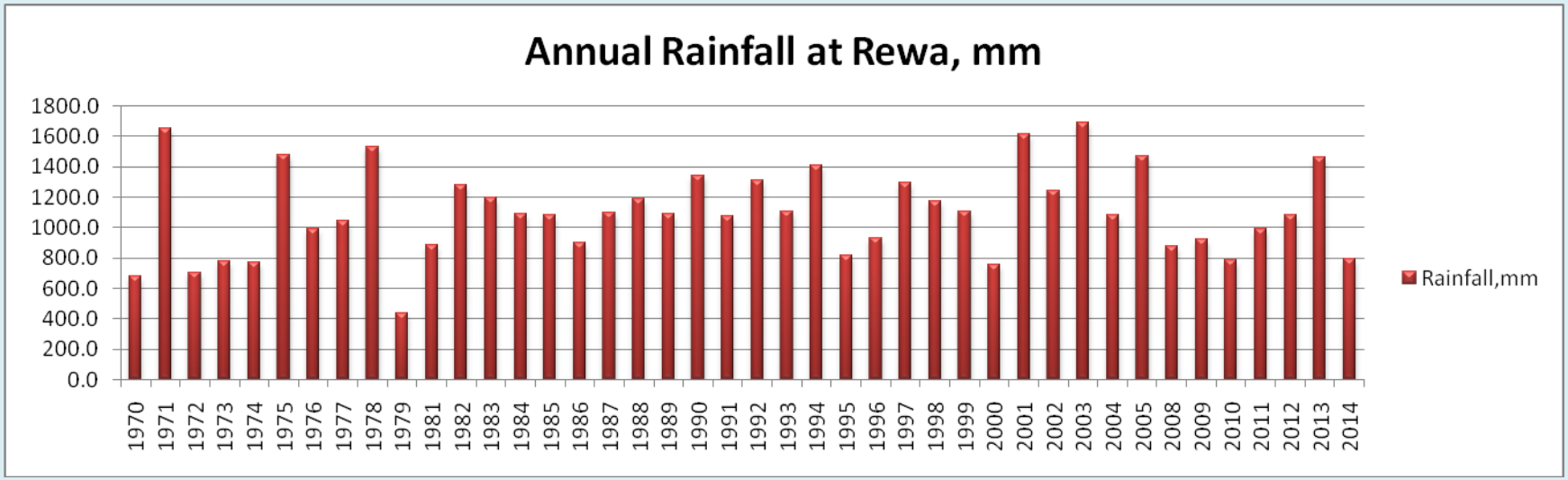
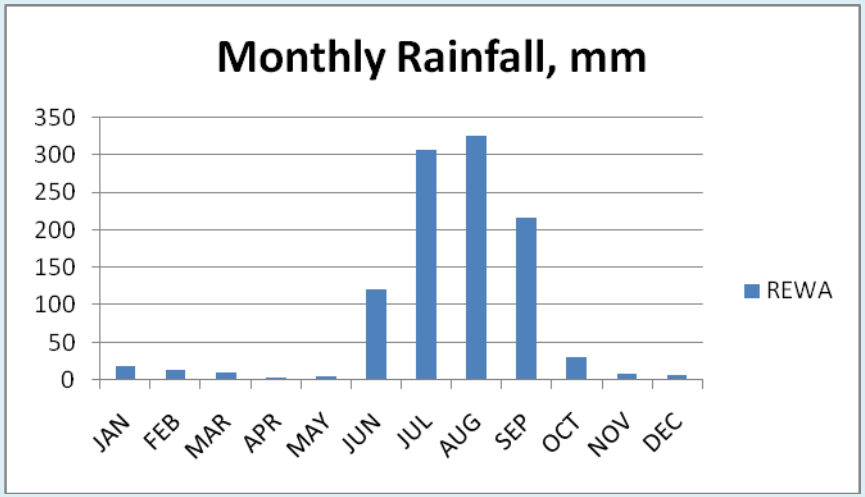


Fig. 15C Rainfall analysis at district Panna, Agro-Climatic Zone – III, Kymore Plateau & Satpura Hills





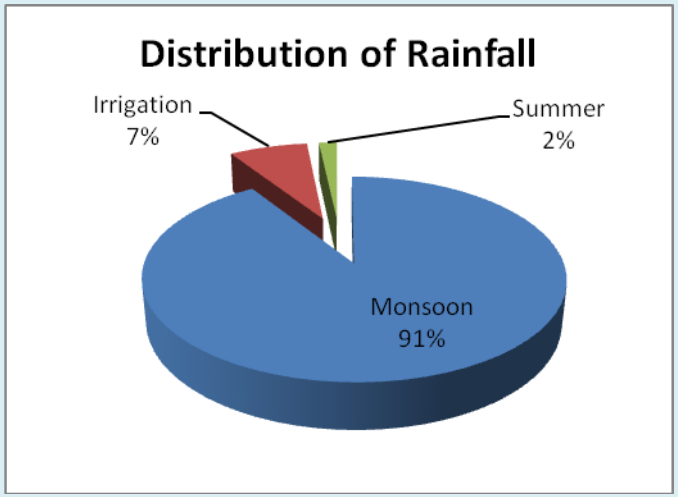
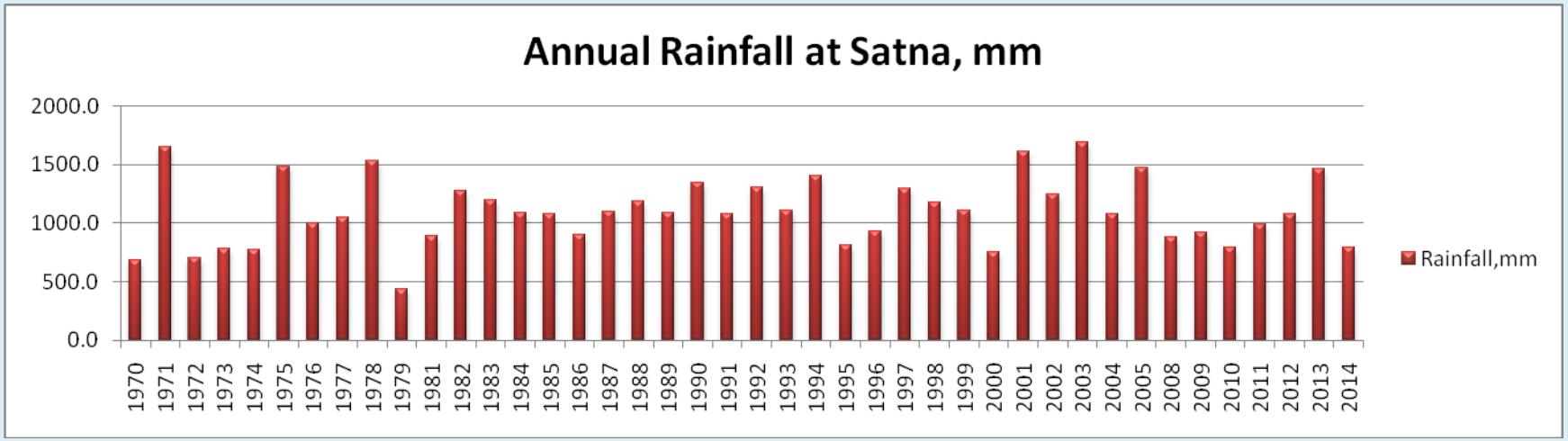
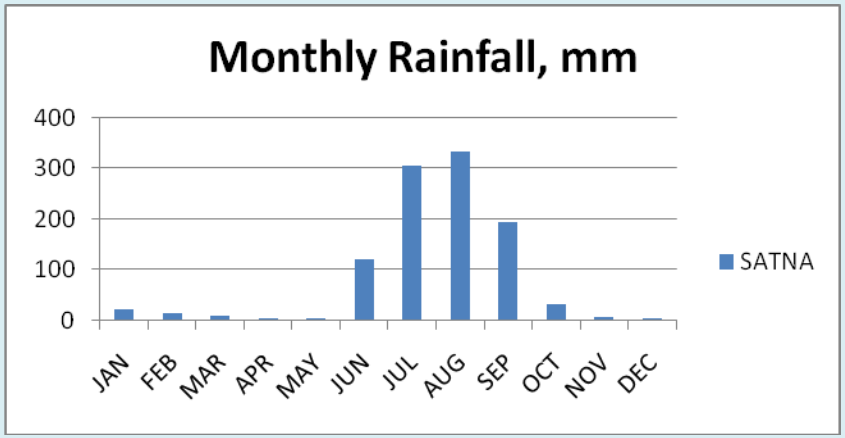


Fig. 15D Rainfall analysis at district Rewa, Agro-Climatic Zone – III, Kymore Plateau & Satpura Hills





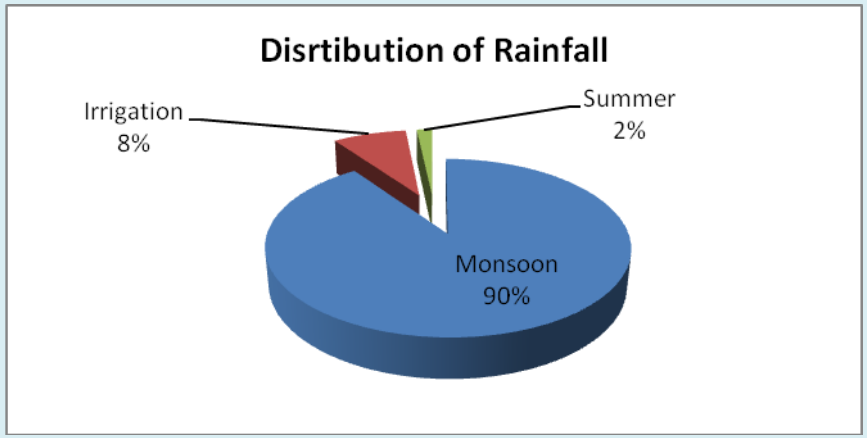
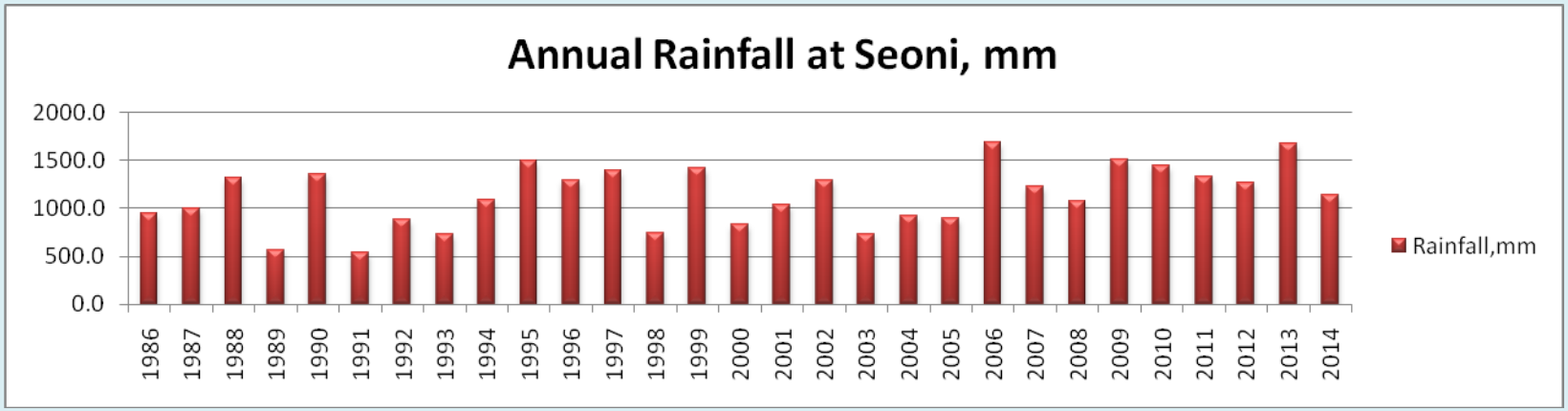
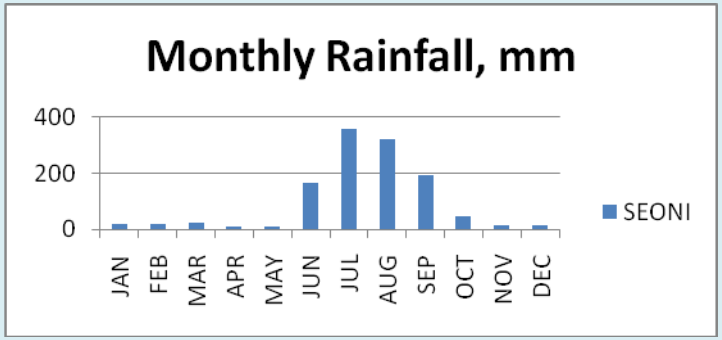


Fig. 15E Rainfall analysis at district Satna, Agro-Climatic Zone – III, Kymore Plateau & Satpura Hills





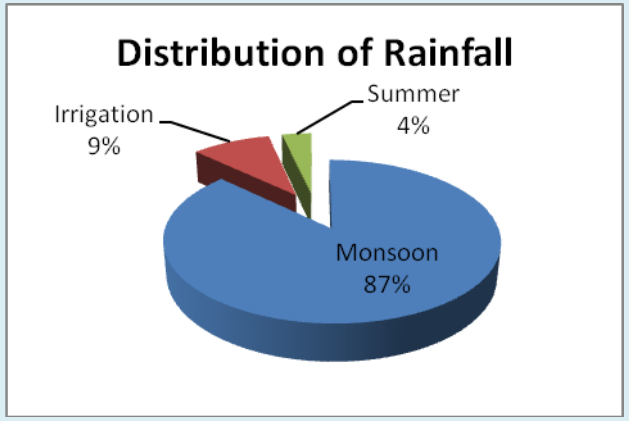
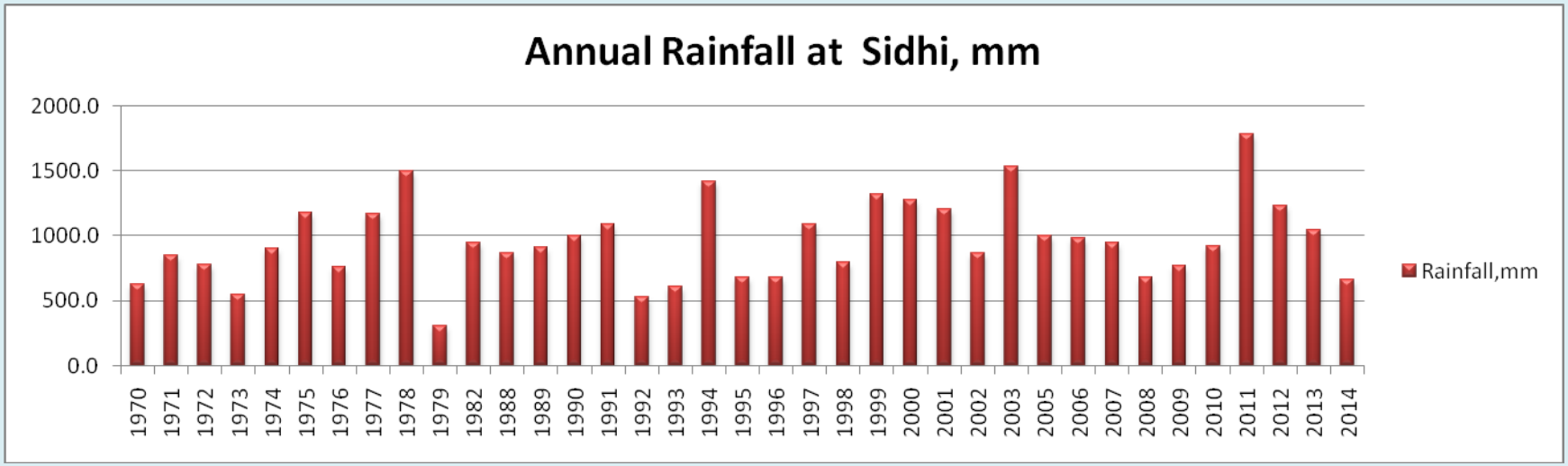
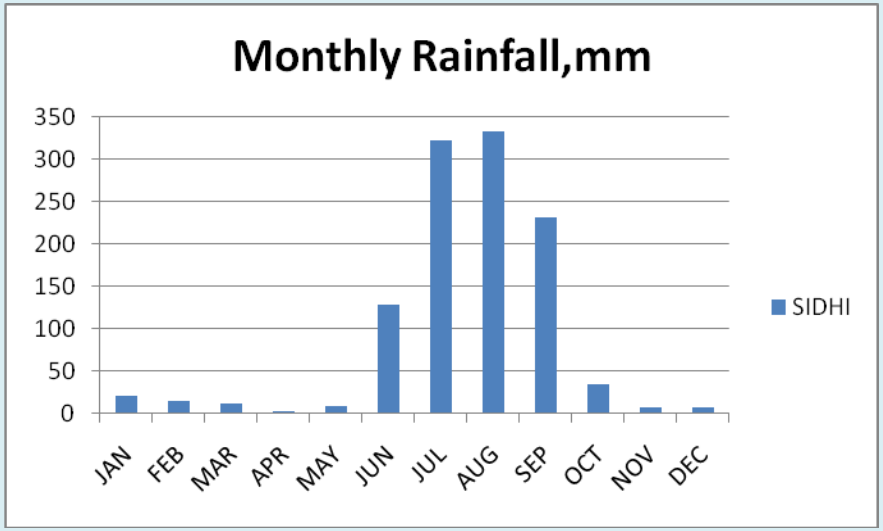


Fig. 15F Rainfall analysis at district Seoni, Agro-Climatic Zone – III, Kymore Plateau & Satpura Hills





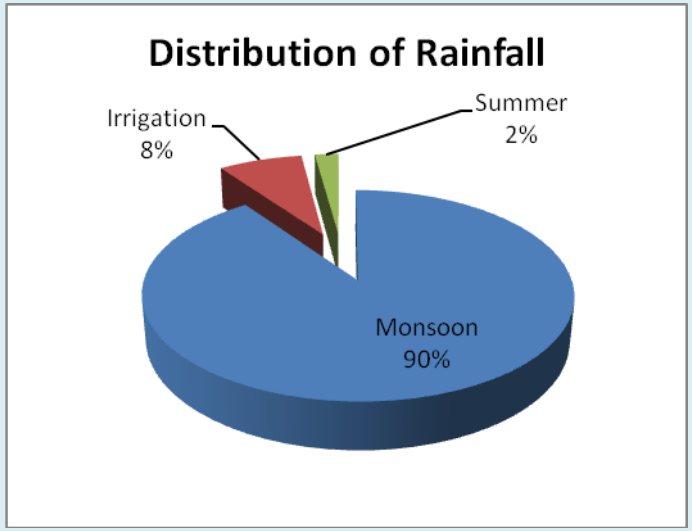


Fig. 15G Rainfall analysis at district Sidhi, Agro-Climatic Zone – III, Kymore Plateau & Satpura Hills

The indigenous cattles are about 29 times more than the cross breed cattle and Jabalpur district has maximum percentage (8%) of cross breed cattle followed by Rewa (5%) and Seoni (4%). This indicates that the zone has tremendous scope for breeding improvement programmes. The population of buffaloes is maximum in Satna (196178) followed by Rewa (170806) and Panna (141895). The sheep is mostly populated in Rewa district which also has maximum number of Goats. Other common animal of the zone is Fowls (667251), dogs (81295) and pigs (55718). Fowls are mostly populated in Seoni and Sidhi district. Katni and Panna districts have thin population of dogs while Rewa and Sidhi district has respectively more population of pigs. The zone has only numeric numbers of animals like rabbits, mules, camels, horses and donkeys.

Water requirement of crops

The zone is a Rice-wheat zone has 689935 ha under rice and 818323ha under wheat. Other major crops are gram (401331 ha), soybean (308663 ha), Pigeon pea (87379 ha), rapeseed and mustard (27760 ha) and maize (43632ha). Apart from this other pulses (rabi) are also taken in 226467 ha and in Kharif it occupies 87379 ha Table 11 A-B. Based on growing period, crop coefficient values, the water requirement of all the crops were worked out and presented in Table 11A. Total yearly water requirement of the crops of the zone is 1742476 ha m. The major user of water, in terms of crop water requirement, is Seoni district (19.56%) followed by Satna (17.355), Rewa (15.36%), Jabalpur (15.13%), and Panna (13.06%). And due to less cropped area, Sidhi required the least water towards crop of 131909 ha m i.e. 7.57% of zonal crop water requirement. Rice and wheat are the major water users. Figure 16-18 depicts crop water requirement of major crops in the districts of the zone.

Area under different vegetables and fruit crops and water requirement thereon is presented in Table 11 B. Coriander is being taken in 2604 ha in the zone and major portion (27.3%) in Jabalpur district with the least in Satna (3.7%). Mango mostly confined in the Rewa district (30.8%) against zonal availability of 4497 ha. Potato is taken in 11493 ha out which maximum is at Rewa and Satna (52.2%). Satna with percentage share of 49.6 % stood first in onion cultivation. Other vegetables are taken in 10324 ha in Kharif in which Panna has the maximum area (25.4%) and Sidhi with only 3.5% area stands last in the zone. Area under other vegetables in rabi (24535 ha) is more than double in comparison to the kharif area.

Table 11 A : Water requirement of field crops in Kymore Plateau & Satpura Hills, ha m

Crops	Jabalpur		Katni		Panna		Rewa		Satna		Seoni		Sidhi	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Rice	81546	67112	107140	88176	80645	60887	119623	81703	82067	61961	150200	109796	68714	49543
Jowar (Kharif)	1434	759	2332	1234	3898	1912	12330	5409	3313	1576	1035	476	10905	5088
Jowar (Rabi)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bajra	0	0	0	0	12	5	292	107	44	18	0	0	5	2
Maize	4323	2510	3354	1947	3477	1871	1141	549	773	403	22047	11113	8517	4358
Ragi	0	0	115	30	0	0	0	0	0	0	0	0	0	0
Wheat	119710	71810	98949	59356	85234	43566	154211	74073	146542	86401	153282	94084	60395	30250
Barley	0	0	392	224	3772	1840	4652	2133	7552	4250	0	0	3812	1823
Other Cereals and Millets (Kharif)	4269	2284	1694	906	580	285	1033	459	1062	521	10293	4891	11250	5272
Other Cereals and Millets (Rabi)	0	0	0	0	87	39	0	0	0	0	22	12	0	0
Gram	59922	33086	41832	23098	83262	39173	59876	26473	93137	50545	44003	24861	19299	8897
Arhar(Tur)	10732	6968	7387	4796	13294	7761	32884	17480	25178	15103	13921	8185	18643	10429
Other Pulses (Rabi)	47403	24558	20192	10461	49128	21687	38263	15873	27572	14040	37193	19716	6716	2905
Other Pulses (Kharif)	20427	10591	4593	2381	15983	7602	14535	6254	17286	8222	8660	3988	5895	2678
Sugarcane	1402	1928	115	158	439	556	43	50	166	218	1083	1432	11	13
Groundnut	158	94	29	17	334	185	3	1	27	15	4523	2347	2	1
Castor seed	0	0	0	0	0	0	0	0	3	4	0	0	0	0
Sesamum	1279	711	5557	3087	36301	18500	3804	1754	6350	3236	2599	1282	9309	4530
Rapeseed and Mustard	3680	1940	2334	1231	4268	1860	4916	2035	3299	1707	1189	632	3533	1502
Linseed	904	499	2103	1161	452	213	9933	4392	2104	1142	7613	4301	4651	2144
Soyabean	43142	19153	981	436	26241	10797	49973	18385	81532	32539	106488	41046	266	104
Niger seed	5661	4422	25	20	51	38	14	9	0	0	4481	3154	44	31
Sunflower	0	0	0	0	0	0	0	0	0	0	4	1	0	0

Safflower	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Oilseeds	0	0	30	19	0	0	264	135	65	37	0	0	66	36
Cotton	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jute	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesta	0	0	0	0	48	33	42	26	4	3	7	5	1	1
Sanhemp	8	7	5	4	78	67	27	21	11	9	97	77	20	16
Other Fibres	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 11 B : Water requirement of fruits and Vegetables crops in Kymore Plateau & Satpura Hills, ha m

Crops	Jabalpur		Katni		Panna		Rewa		Satna		Seoni		Sidhi	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Chillies	36	38.6	308	330.3	356	363.9	263	248.5	773	830.2	296	322.8	147	145.8
Ginger	10	12.7	328	416.3	0	0.0	26	27.6	354	426.9	454	549.7	55	61.4
Turmeric	0	0.0	178	225.0	0	0.0	17	17.9	68	81.7	16	19.3	12	13.3
Betel nut	0	0.0	0	0.0	0	0.0	0	0.0		0.0		0.0	0	0.0
Garlic	9	14.9	102	169.4	131	202.5	106	149.8	202	322.8	320	515.4	28	41.7
Coriander	717	1076.2	191	286.7	821	1091.9	338	412.7	96	136.1	298	426.1	143	183.8
Other Condiments and Spices	4	4.9	105	127.6	38	44.0	0	0.0	7	8.5	41	50.7	22	24.7
Mango	558	926.8	701	1164.3	339	524.1	1387	1960.6	956	1527.7	402	647.5	154	229.6
Banana	7	15.0	19	40.8	0	0.0	1	1.8	0	0.0	3	6.3	2	3.9
Citrus Fruits	1	1.3	23	30.7	0	0.0	0	0.0	5	6.4	174	225.3	0	0.0
Grapes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Papaya	0	0.0	42	71.4	14	22.2	5	7.2	13	21.3	3	4.9	1	1.5
Other Fruits	624	1036.4	671	1114.5	77	119.1	75	106.0	145	231.7	435	700.7	0	0.0
Potato	229	211.8	1349	1247.6	1683	1374.7	2463	1903.4	3536	3258.8	1229	1150.3	606	483.8
Sweet Potato	1	0.7	74	54.8	289	196.4	9	5.5	56	38.1	17	11.2	13	8.4
Onion	164	288.4	1007	1770.9	817	1337.5	2876	4304.5	5771	9764.5	714	1217.7	283	446.7
Other Vegetables (Kharif)	1528	1131.8	1658	1228.1	2623	1782.3	717	440.7	2187	1486.1	1245	819.1	366	237.5
Other Vegetables (Rabi)	13347	9826.1	2146	1579.9	1938	1215.7	1010	595.4	2855	2065.9	2585	1947.3	654	402.0
Opium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tobacco	0	0.0	0	0.0	0	0.0	12	6.4	9	5.3	0	0.0	0	0.0
Other Plantation Crops	34	63.1	113	209.8	195	337.0	36	56.9	22	39.3	33	59.4	0	0.0
Fodder Crops	398	300.3	0	0.0	0	0.0	71	44.5	33	22.8	944	632.6	0	0.0
Other Non Food Crops	155	209.4	14	18.9	0	0.0	0	0.0	13	16.6	51	65.6	0	0.0

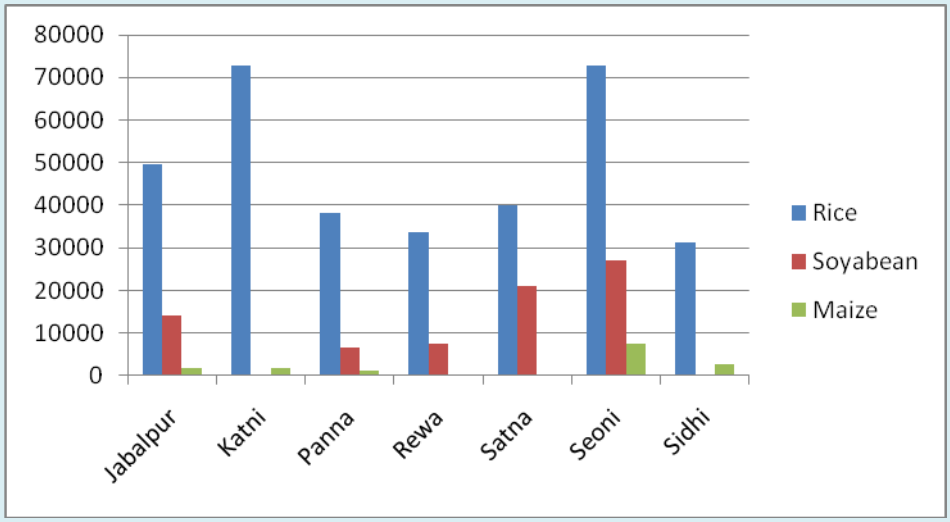


Fig. 16 Crop water requirement of major kharif crops of ACZ III - Kymore Plateau & Satpura Hills in ha m

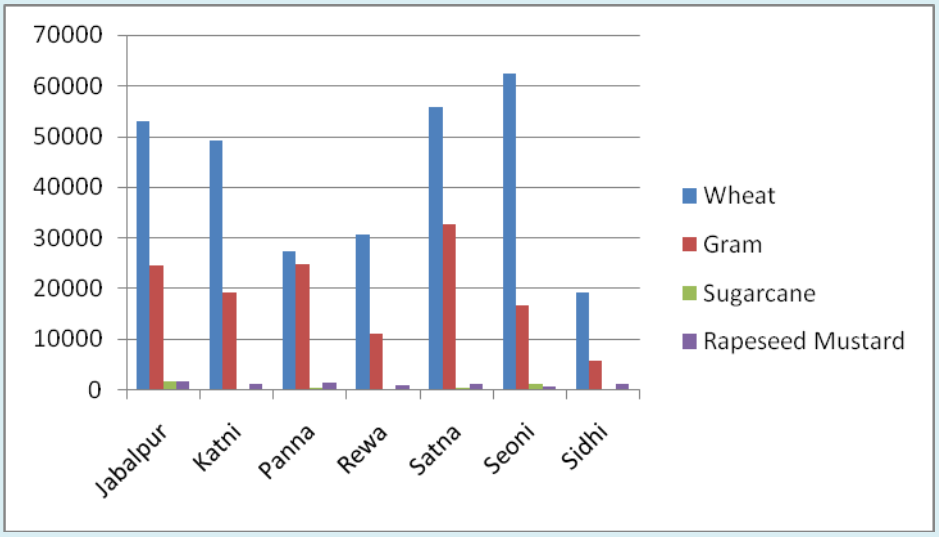


Fig. 17 Crop water requirement of major rabi crops of ACZ III -Kymore Plateau & Satpura Hills in ha m

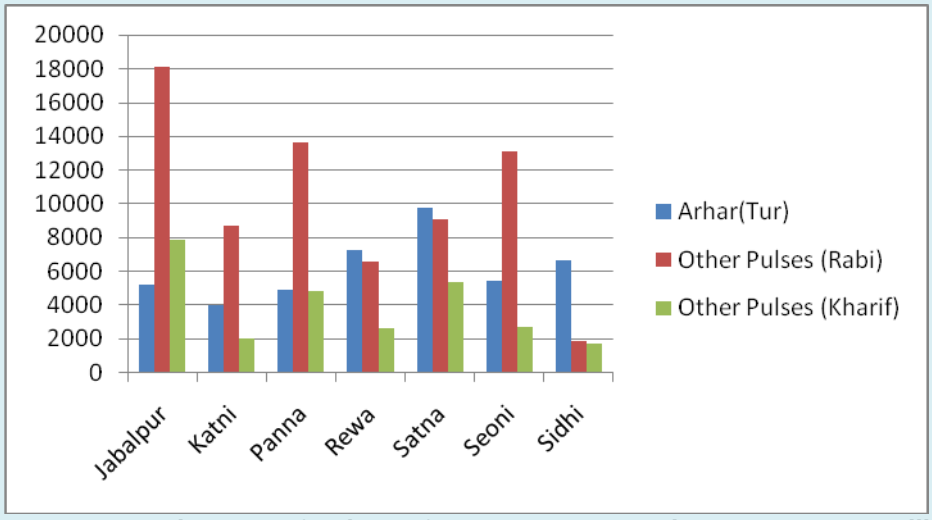


Fig. 18 Crop water requirement of pulses of ACZ III - Kymore Plateau & Satpura Hills in ha m

Water budget

The agroclimatic zone III (ACZ III)- Kymore Plateau and Satpura Hills receives total quantum of water towards rainfall as 5273632 ha-m. Maximum (21.9 %) of it receives in district followed by Panna (15.8 %), Satna (15.2 %) and Rewa (13.6%). The least water as rainfall falls in Sidhi district which is 10.5 % of zonal total (Table 12). National Commission on Agriculture has laid down norms for water budgeting of an area and as per its estimate the losses of water as evaporation, surface water flow and ground water flow out of the area is calculated in present estimation. Similarly, addition of water into the area as runoff generated from the zone, addition of soil moisture and to the ground water is also computed. The water budget so generated for ACZ III is presented in Table 12. The immediate evaporation losses that occurs during the rainfall is taken as 17.5% of total rainfall and it is 922886 ha-m for the zone, 28.7% rainfall converts into surface flow and it is 1513532 ha-m. It is considered that 10.549 % (251443 ha-m) of surface flow goes out of the zone. Ground water also adds to the surface flow and it is taken as 23.739% of surface flow. Thus, surface flow arrives to be 2383576 ha m which is 45.198% of total precipitation.

Evaporation takes place from open water body, soil surface, forest and vegetation and also from rise of water table, and, respectively it is taken as 7.196% (188684 ha-m) of total surface flow, 31.504% (739242 ha-m) of total soil moisture storage, 30.826% (723333 ha-m) of total soil moisture and 18.5451% (209125 ha-m) of total ground water. Part of rainfall as recharge enriches ground water and it is 12.5 % (659204 ha-m). There is an addition to the ground water from streams and flood flows which is 4.851 % (115627 ha-m) of total surface flow. The total utilizable surface ground water for the ACR III computed as 1517788 ha-m.

The soil moisture increases due to rainfall as well as from irrigation. 41.3% of rainfall and 7.067% of total surface flow is considered as soil moisture storage. Total zonal soil moisture storage is 2178010 ha-m and out of this 883998 ha-m is available as ET for the crops. Each and every district of the ACZ III zone contributes in same proportion in zonal water budgeting as the quantum of rainfall of each district contributes in zonal rainfall quantum owing to rainfall based water distribution.

Table 12 : Water budgeting of Kymore plateau and Satpura hills, ha-m

S.N	Particulars	Jabalpur	Katni	Panna	Rewa	Satna	Seoni	Sidhi	Zone Total
1	Normal rainfall, ha m	637742	577410	831488	718655	800119	1153428	554790	5273632
2	Immediate evaporation (17.5%)	111605	101047	145510	125765	140021	201850	97088	922886
3	Surface flow (28.7%)	183032	165717	238637	206254	229634	331034	159225	1513532
4	From outside state(10.549% of total surface flow)	30407	27531	39645	34265	38149	54995	26452	251443
5	To GW from flood flows (-4.851% of total surface flow)	-13983	-12660	-18231	-15757	-17543	-25290	-12164	-115627
6	From GW to surface flow(23.739% of total surface flow)	68427	61954	89215	77108	85849	123758	59526	565837
7	From irrigated area to surface flow(7.067% of total surface flow)	20370	18443	26559	22955	25557	36842	17721	168447
8	Total surface flow(45.198% of total ppt)	288247	260978	375816	324818	361638	521326	250754	2383576
9	Evaporation losses from reservoirs and tanks (7.916% of total surface flow)	22818	20659	29750	25713	28627	41268	19850	188684
10	Flow into seas and outside state (43.445% of total surface flow)	125229	113382	163273	141117	157114	226490	108940	1035545
11	Utilizable surface flow (48.639% of total surface flow)	140200	126937	182793	157988	175897	253568	121964	1159348
12	Water available for ground water storage (12.5%)	79718	72176	103936	89832	100015	144179	69349	659204
13	From streams and flood flows to GW(4.851% of total surface flow)	13983	12660	18231	15757	17543	25290	12164	115627
14	From irrigation to GW addition (S.N.15-(12+13))	43363	39261	56537	48865	54404	78427	37723	358578
15	Total GW (21.492% of total ppt)	137064	124097	178703	154453	171962	247895	119235	1133409
16	Evaporation and rise of water table (18.451% of total GW)	25290	22897	32973	28498	31729	45739	22000	209125
S.N	Particulars	Jabalpur	Katni	Panna	Rewa	Satna	Seoni	Sidhi	Total

17	Regeneration into streams(49.924% of total GW)	68428	61954	89216	77109	85850	123759	59527	565843
18	GW available utilization(31.625% of total GW)	43346	39246	56515	48846	54383	78397	37708	358441
19	Total utilizable surface + GW (S.N. 11+18)	183547	166183	239308	206834	230280	331965	159672	1517788
20	Soil moisture storage (41.3% of normal rainfall)	263387	238470	343405	296805	330449	476366	229128	2178010
21	From irrigated area to soil moisture(7.067% of total surface flow)	20370	18443	26559	22955	25557	36842	17721	168447
22	Total soil moisture storage (44.495% of total ppt)	283763	256919	369971	319766	356013	513218	246854	2346503
23	Evaporation losses from soil moisture (31.504% of total soil moisture storage)	89397	80940	116556	100739	112158	161684	77769	739242
24	Evap. losses from forest and other veg. (30.826% of total soil moisture)	87473	79198	114047	98571	109745	158205	76095	723333
25	Soil moisture available for ET from crops (37.673 % of total soil moisture)	106902	96789	139379	120465	134121	193345	92997	883998
26	Water requirement of crops	194680	156593	145055	170323	195477	153085	83480	1098693
27	Water requirement of animal husbandry	4472	4583	5394	10379	10086	6155	5221	46290
28	Domestic water requirement	12125	6364	5006	11647	10981	6794	5551	58468
29	Industrial Water requirement @ 6 % of available fresh water	28835	25252	26390	28825	39475	51418	23763	223958
30	Water available for utilization (S.N. 19+25)	290449	262972	378687	327299	364401	525309	252670	2401786
31	Water required for different sectors (26+27+28+29)	240112	192792	181845	221174	256019	217452	118015	1427409
32	Surplus or deficit of water in the district (30-31)	50337	70180	196842	106125	108382	307857	134655	974377

Utilization of water takes place in four major categories. These are domestic and animal water needs, crop water requirement and requirement of water for industrial and recreation. Water needs of different sectors in districts of ACR III is presented in

Fig. 19. Total crop water requirement of the zone is 1098693 ha-m and out of which Jabalpur and Satna needs maximum water towards crops as each has 17.8% of zonal total. The least crop water demand comes from Sidhi district (7.6 %). In comparison to the crop water demand the water demand towards domestic and animal husbandry is very low as it is respectively 58468 ha-m and 46290 ha m. Owing to higher population in Jabalpur, Rewa and Satna districts, the domestic demand is about 60 % of the zonal demand. Panna registers the least domestic water demand i.e. only 8.6%. The Rewa and Satna districts have more animal husbandry and demand for 44.2% of the zonal water needs of it. Jabalpur and Katni both requires less than 10% each. The industrial demand is computed as 6% of available water thus total zonal demand comes out as 223958 ha-m.

Total water needs and supply of different districts of ACR III is presented in Fig. 20. The excess of water is also shown in the figure. The water available for utilization at zonal level is 2401786 ha-m. The maximum share (21.9%) is available at Seoni district followed by Panna (15.8 %), Satna (15.2%) and Jabalpur (12.1 %). The total zonal water demand is 1427409 ha-m and Satna district requires the maximum share of 17.9 % followed by Jabalpur(16.8 %) and Rewa (15.5%). The Sidhi district requires the least water i.e. 8.3 % of the zonal total. As for as the excess water concerns the zone has 974377 ha-m of surplus water and maximum of it lies in Seoni District (31.6%) followed by Panna (20.2 %) and Sidhi (13.8%). The least share of 5.2 % is available as surplus water in Jabalpur district. An abstract in pictorial form is provided in Fig 21.

Interestingly, Districts Jabalpur (16.8 %), Katni (13.5 %), Rewa (15.5 %)) and Satna (17.9 %) requires more water than the zonal share of availability which is respectively 12.1 % , 10.9 %, 13.6 % and 15.2 % for these districts. But when within the distrct demand supply is taken into account it is find out that Jabalpur, Katni, Panna, Rewa, Satna, Seoni and Sidhi district has 20.97%, 36.40%, 108.24%, 47.98%, 42.33%, 141.57% and 114.10% excess water within them. Taking net sown area of these district, as per Directorate of Extension and Farmers Welfare, 278708 ha, 216784 ha, 271957 ha, 363063 ha, 352774 ha, 396876 ha and 169458 ha, the per hectare water availability due to this surplus water comes out to be 18.06 cm, 32.37 cm, 72.38 cm, 29.23 cm, 30.72 cm 77.57 cm and 79.46 cm. It means, the future plans to enhance crop production or alternate cropping may be based on this much depth of water.

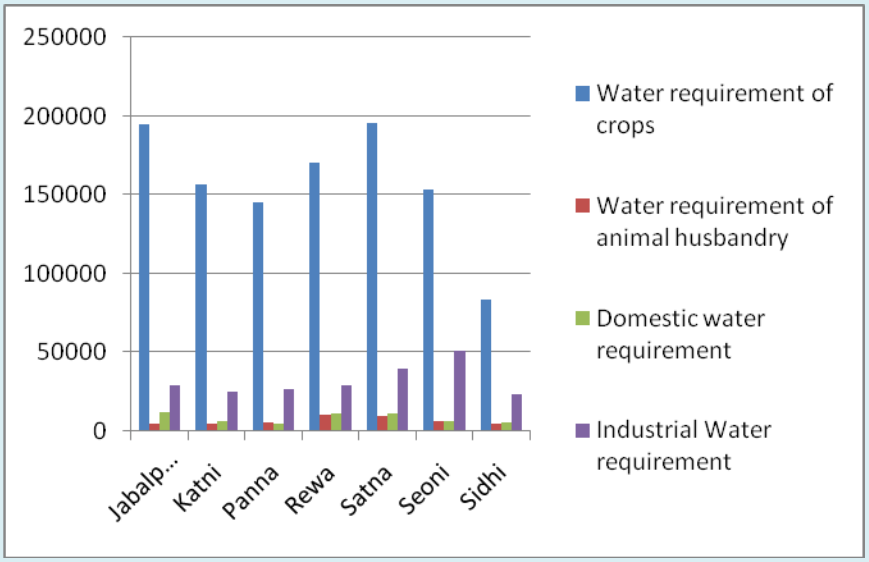


Fig. 19 Water needs of different sectors in districts of ACZ III Kymore Plateau & Satpura Hills (ha-m)

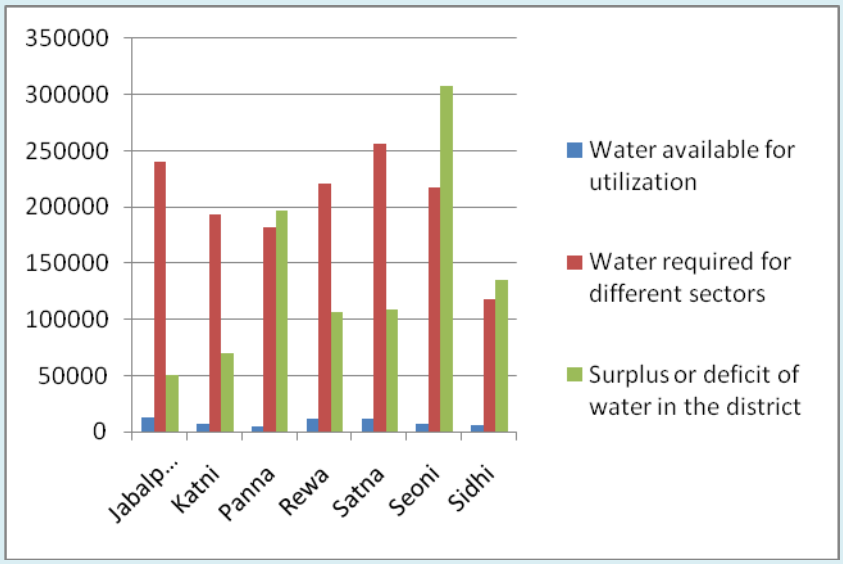
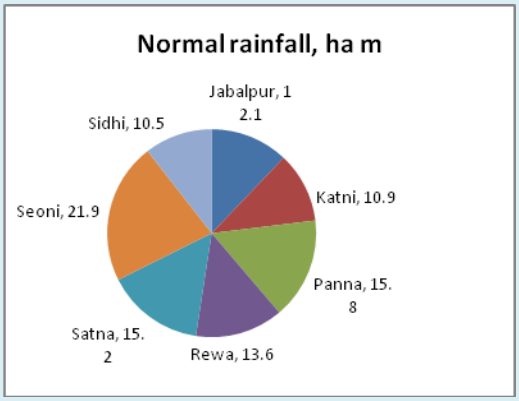
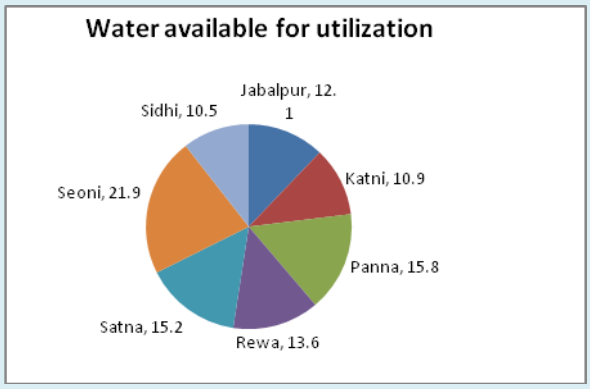
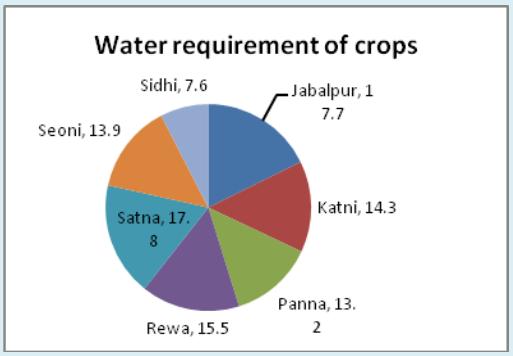
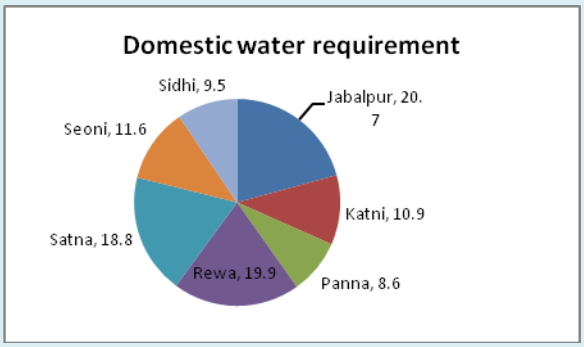


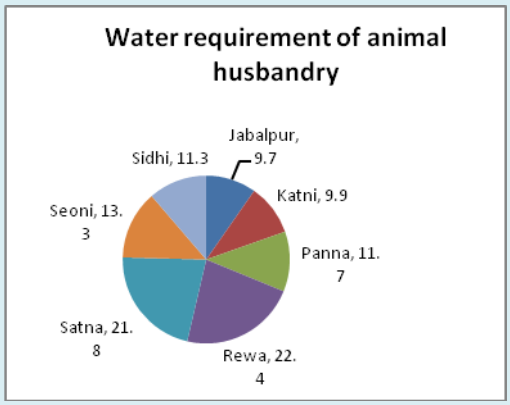
Fig. 20 Total Water needs and supply of different districts of ACZ III Kymore Plateau & Satpura Hills (ha-m)











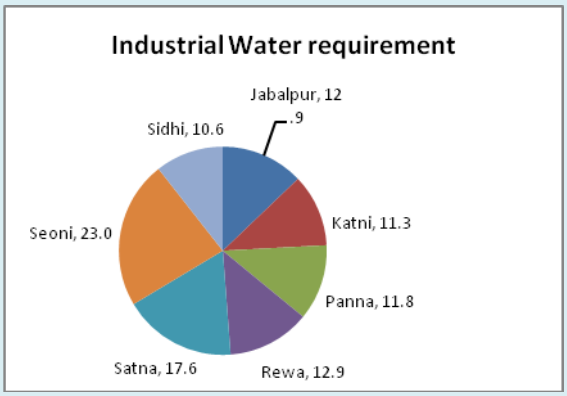


Fig. 21 Abstract of water of different districts of ACZ III Kymore Plateau & Satpura Hills (ha-m)

Agroclimatic Zone IV - Central Narmada Valley

The Agroclimatic zone IV – Central Narmada Valley has two districts namely Hoshangabad and Narsinghpur. It comes under Wheat zone having deep black soils. The zone has total geographical area of 1182340 ha, out of which forest area is 33.2 %. Net area sown is 52.7 %. Out of total net sown area of 623303 ha, the fallow land including current fallow is 2.4%. District land utilization is presented in Table 13.

Rainfall analysis

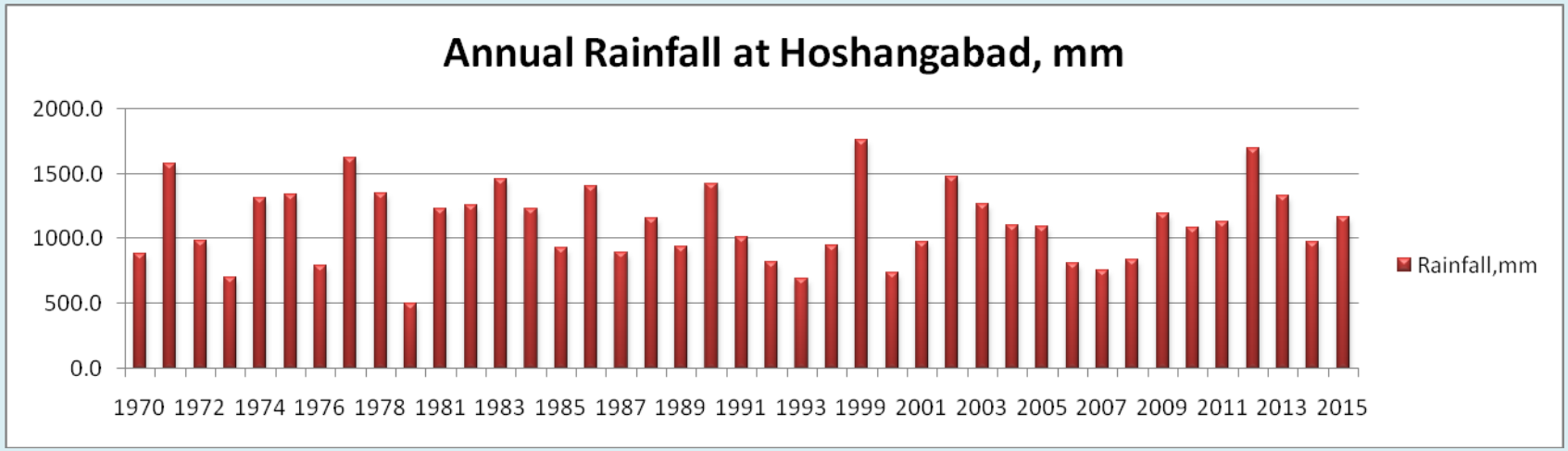
Annual normal rainfall is 1200 to 1600 mm. On an average 93 % of this rainfall occurs during monsoon i.e. June to September, 6% in winter i.e. late December and 1 % in summer. Maximum rainfall occurs in the month of August followed by the month July. The pattern of annual rainfall occurred in years 1970 to 2014 is presented in Fig. 22 A-B. The record also shows maximum ever rainfall of 1963 mm (1977) was occurred in the Narsinghpur. The annual rainfall exceeded 14.6% and 32.3% times than the normal annual rainfall in Hoshangabad and Narsinghpur districts respectively.

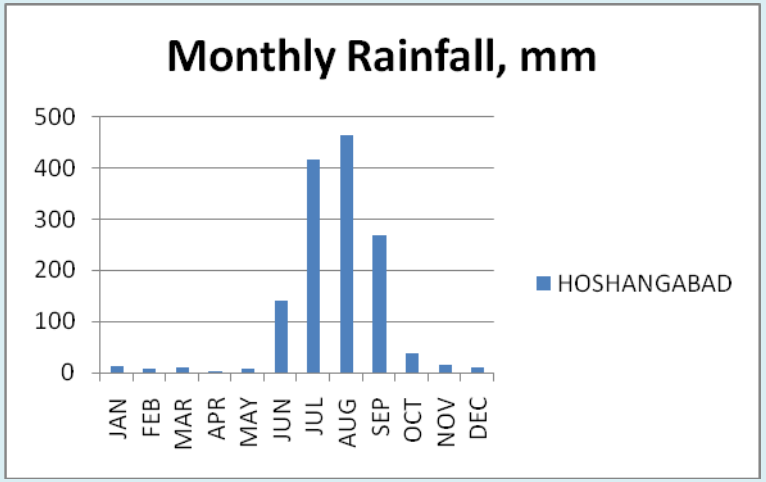
Domestic and livestock water needs

Total population of the zone is 2333116 as per Census 2011. Total human water needs of the zone is 11496 ha m ha m. Table 14 illustrates water requirement towards human needs as well as for live stock. Live stock population comprises of cattle both cross breed and indigenous, buffalo, bovine, sheep, goat, horses and ponnies, mules, donkey, pigs, dogs, rabbits, fowls, ducks, turkey and other poultry. The indigenous cattles are about 10 times more than the cross breed cattle. Narsinghpur has more cross breed cattles as against Hoshangabad as its percentage is 13.5% in comparison to Hoshangabad percentage of 6.1% of total available cattles of these districts. Both districts have scope of breeding improvement programmes. Bovine is the main cattle class (900871) followed by population of buffaloes (239756). Except fowls in the Hoshangabad (154219) which is three times more than the Narsinghpur all other animals are found in these two districts are more or less of the same quantity.

Table 13 Total Area and Classification of Area In Each District of Central Narmada Valley MADHYAPRADESH State for the year ending 2013- 14															
DISTRICT NAME	Reporting Area For Land Utilization Statics			Not Available For Cultivation			Other Uncultivated Land Excluding Fallow Land			Fallow Land		Total	Net Area Sown	Total Cropped Area	Area Sown more than once
		Forests	Area Under Non Agricultural Uses	Barren and Unculturable Land	Total	Permanent Pastures and Other Grazing Lands	Land Under Misc Tree crops and Groves not Included in Net Area	Culturable Waste Land	Total	Fallow Lands Other than Current Fallows	Current Fallows				
(1)	(2)	(3)	(4)	(5)	6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
HOSHANGABAD	668689	256101	44640	2429	47069	25464	17	17580	43061	5696	2768	8464	313994	636209	322215
NARSINGHPUR	513651	136184	25555	1020	26575	24139	168	10581	34888	3793	2902	6695	309309	471782	162473
Total	**1182340**	**392285**	**70195**	**3449**	**73644**	**49603**	**185**	**28161**	**77949**	**9489**	**5670**	**15159**	**623303**	**1107991**	**484688**

Table 14 : Live stock and Human water needs of ACZ IV			
	Hoshangabad	Narsinghpur	Zone Total
Cross breed Cattle	20369	38080	58449
Water Req. (l/day)	3055350	5712000	8767350
Indigenous Cattle	319633	283033	602666
Water Req. (l/day)	31963300	28303300	60266600
Buffalo	112526	127230	239756
Water Req. (l/day)	16878900	19084500	35963400
Bovine	452528	448343	900871
Water Req. (l/day)	67879200	67251450	135130650
Sheep	61	744	805
Water Req. (l/day)	610	7440	8050
Goat	80059	106612	186671
Water Req. (l/day)	800590	1066120	1866710
Horse & Ponies	254	256	510
Water Req. (l/day)	8255	8320	16575
Mules	5	20	25
Water Req. (l/day)	162.5	650	812.5
Donkey	284	555	839
Water Req. (l/day)	9230	18037.5	27267.5
Camels	2	1	3
Water Req. (l/day)	230	115	345
Pigs	2396	2825	5221
Water Req. (l/day)	23960	28250	52210
Dogs	16601	11743	28344
Water Req. (l/day)	83005	58715	141720
Rabbits	109	6	115
Water Req. (l/day)	69.76	3.84	73.6
Elephants	0	2	2
Water Req. (l/day)	0	300	300
Fowls	154219	37120	191339
Water Req. (l/day)	38554.75	9280	47834.75
Ducks	75	137	212
Water Req. (l/day)	18.75	34.25	53
Turkeys	13	0	13
Water Req. (l/day)	3.25	0	3.25
Other Poultry	47	29	76
Water Req. (l/day)	11.75	7.25	19
TWR lpd	121900632	122605259	244505891
TWR ha m	4407	4436	8843
Human Population	1240976	1092141	2333116
TWR human, ha m	6115	5382	11496





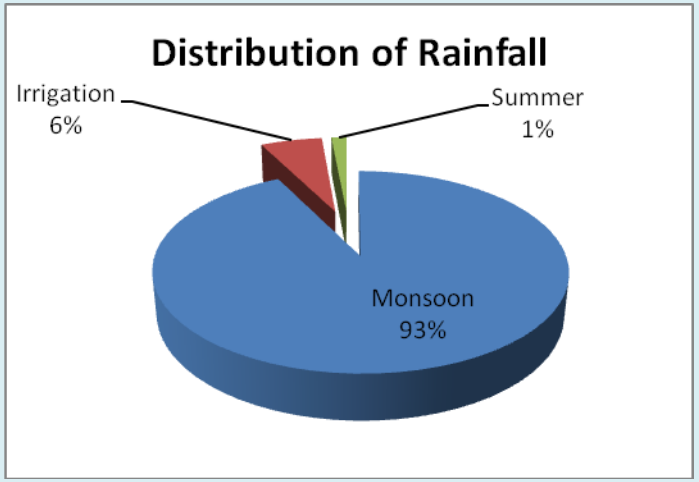
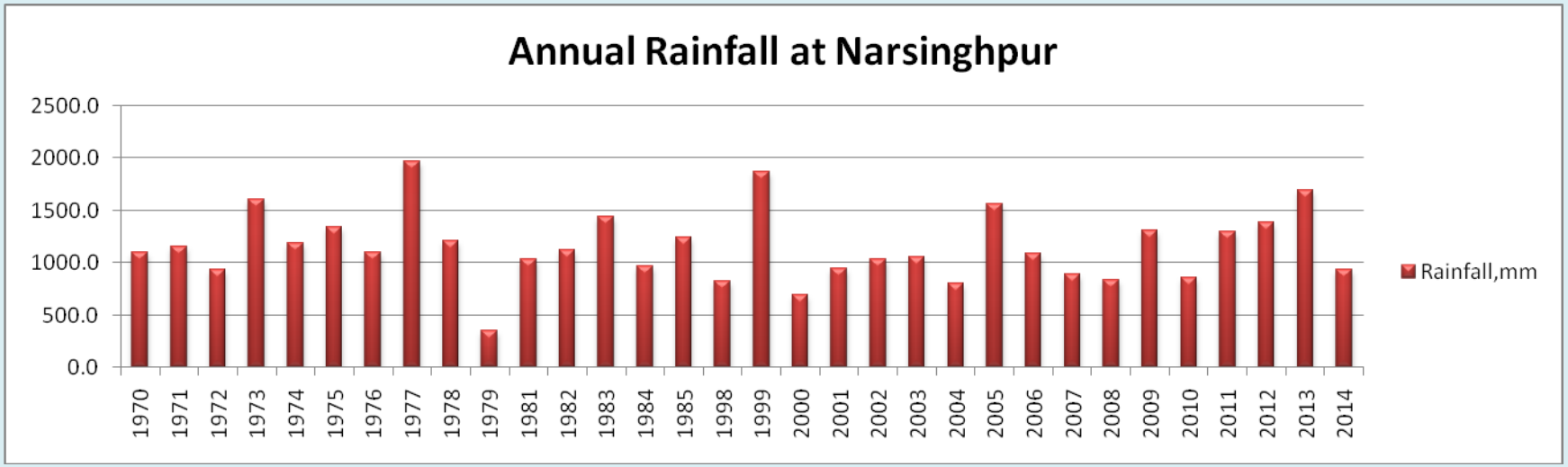
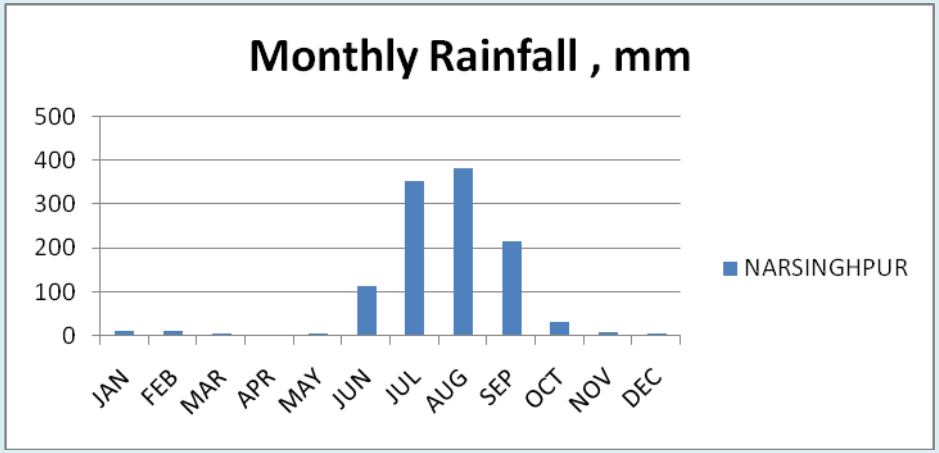


Fig. 22A Rainfall analysis at district Hoshangabad, Agro-Climatic Zone – IV, Central Narmada Valley





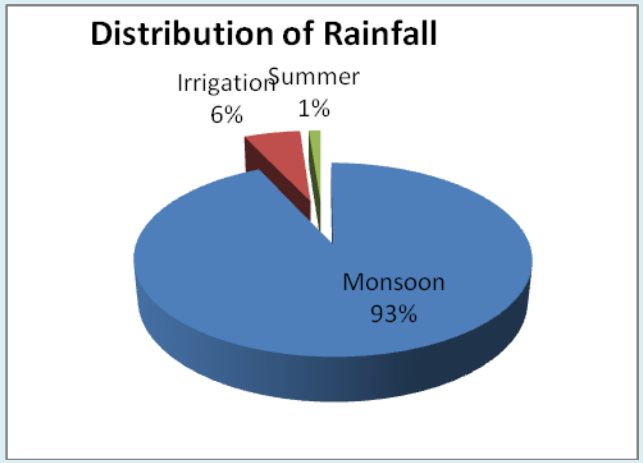


Fig. 22B Rainfall analysis at district Narsinghpur, Agro-Climatic Zone – IV, Central Narmada Valley

Water requirement of crops

The zone is a Wheat zone has 353429 ha under wheat in which Hoshangabad has contribution of 73.6%. Rice is grown in 59303 ha. Other major crops are gram (134819 ha), Pigeon pea (33872 ha). Apart from this other pulses (rabi) are also taken in 56669 ha and in Kharif it occupies 87346 ha Table 15A -B. Narsinghpur is dominated in pigeon pea (99.1%) and pulse cultivation (94.3%). Sugercane is also coming up in steady way as now it is grown in 40960 ha area of Narsinghpur. In kharif Soybean is the main crop and growing in 333038 ha mostly in Hoshangabad (64.2%). Based on growing period, crop coefficient values, the water requirement of all the crops were worked out and presented in Table 15A. However, based on irrigated area the water requirement of major crops were also calculated and presented Fig. 23 to Fig 25. For the zone Wheat is the major rabi crops and its water requirement is 13640 ha-m. Sugercane is another crop water requirement is 38450 ha-m. (Fig.23).

Vegetables and fruit crops are shown in Table 15 B. Coriander is taken in 929 ha at zone level and about two third in Narsinghpur. Potato is in 60:40 ratio between both the city totaling 1015 ha. Onion is confined in Narsinghpur i.e. 86.3% of zonal total of 2633 ha. Almost equal, 1638 ha and 1648 ha, is under other vegetables in kharif and rabi respectively in Hoshangabad. Whereas in the both districts vegetable crops are being taken in 3503 ha and 4217 ha respectively.

Water budget

The agroclimatic zone IV (ACZ IV)- Central Narmada Valley receives total quantum of water towards rainfall as 1599893 ha m. National Commission on Agriculture has laid down norms for water budgeting of an area and as per its estimate the losses of water as evaporation, surface water flow and ground water flow out of the area is calculated in present estimation. Similarly, addition of water into the area as runoff generated from the zone, addition of soil moisture and to the ground water is also computed. The water budget so generated for ACZ IV is presented in Table 16. The immediate evaporation loss that occurs during the rainfall is taken as 17.5% of total rainfall and it is 279981 ha-m for the zone. 28.7% rainfall converts into surface flow and it is 459169 ha-m. It is considered that 10.549 % (76282 ha-m) of surface flow goes out of the zone.

Table 15 A : Water requirement of field crops in Central Narmada Valley, ha m

Crops	Narsinghpur		Hoshangabad	
	Area	CWR	Area	CWR
Rice	18364	12524	40939	31851
Jowar (Kharif)	1121	484	12	6
Jowar (Rabi)	0	0	0	0
Bajra	9	3	18	7
Maize	1017	481	1425	761
Ragi	0	0	0	0
Wheat	93171	49468	260258	166999
Barley	4	2	7	4
Other Cereals and Millets (Kharif)	445	197	154	78
Other Cereals and Millets (Rabi)	0	0	0	0
Gram	104286	50965	30533	18034
Arhar (Tur)	33600	18048	272	170
Other Pulses (Rabi)	53459	24513	3210	1779
Other Pulses (Kharif)	13400	5757	73946	36244
Sugarcane	40960	49611	3102	4320
Groundnut	104	51	54	30
Castor seed	0	0	4	5
Sesamum	429	197	57	30
Rapeseed and Mustard	27	12	295	167
Linseed	5	2	0	0
Soyabean	101854	36876	213184	87022
Niger seed	36	24	0	0
Sunflower	23	7	0	0
Safflower	0	0	0	0
Other Oilseeds	6	3	0	0
Cotton	0	0	0	0
Jute	0	0	0	0
Mesta	0	0	0	0
Sanhemp	3	2	0	0
Other Fibres	0	0	279	195

Table 15 B : Water requirement of fruits and vegetables crops in Central Narmada Valley, ha m

Crops	Narsinghpur		Hoshangabad	
	Area	CWR	Area	CWR
Chillies	209	211	376	431
Ginger	162	179	76	97
Turmeric	10	11	20	26
Betel nut	0	0	0	0
Garlic	168	249	68	115
Coriander	627	803	302	454
Other Condiments and Spices	29	33	87	113
Mango	28	41	171	288
Banana	0	0	0	0
Citrus Fruits	16	19	144	195
Grapes	0	0	0	0
Papaya	18	27	10	17
Other Fruits	72	107	241	406
Potato	603	501	412	406
Sweet Potato	139	85	231	162
Onion	2272	3562	361	645
Other Vegetables (Kharif)	1865	1145	1638	1147
Other Vegetables (Rabi)	2569	1674	1648	1298
Opium	0	0	0	0
Tobacco	0	0	0	0
Other Plantation Crops	72	119	11	21
Fodder Crops	596	373	2662	1898
Other Non Food Crops	4	5	2	3

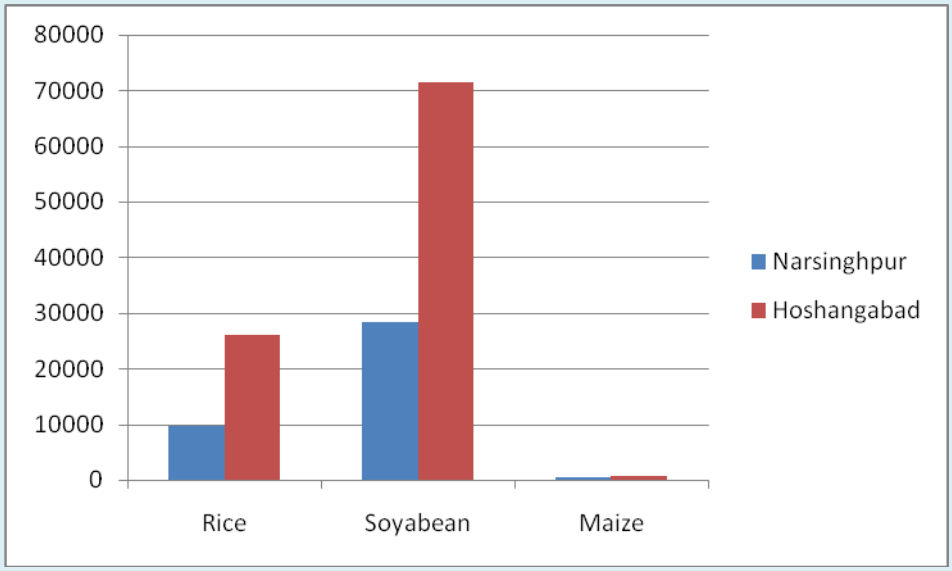


Fig. 23 Crop water requirement of major kharif crops of ACZ IV- Central Narmada Valley in ha m

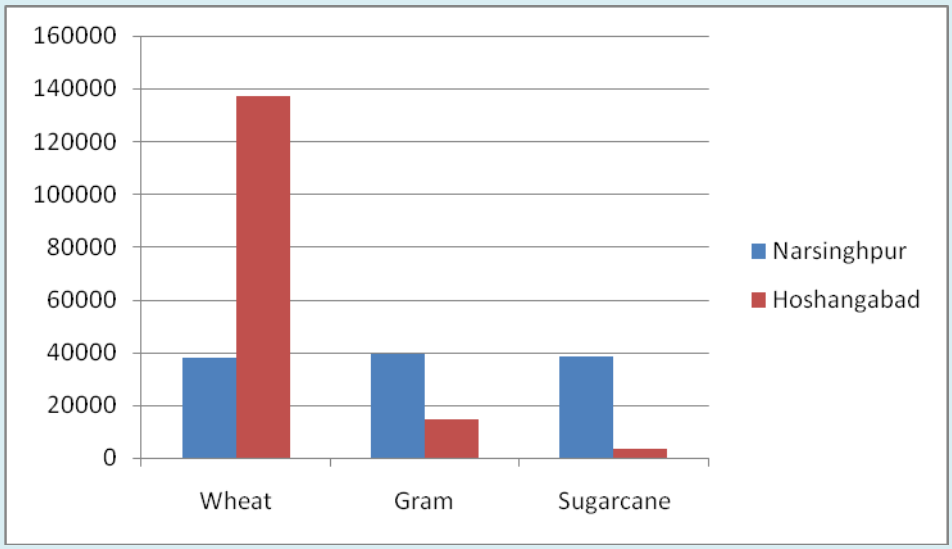


Fig. 24 Crop water requirement of major rabi crops of ACZ IV - Central Narmada Valley in ha m

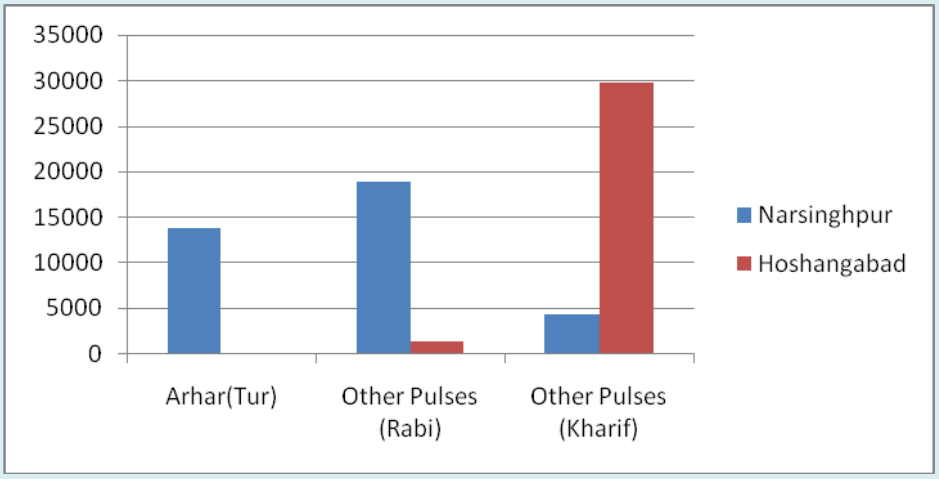


Fig. 25 Crop water requirement of pulse crops of ACZ IV - Central Narmada Valley in ha m

Ground water also adds to the surface flow and it is taken as 23.739% of surface flow. Thus, surface flow arrives to be 723120 ha-m which is 45.198% of total precipitation.

Evaporation takes place from open water body, soil surface, forest and vegetation and also from rise of water table, and, respectively it is taken as 7.916% (57242 ha-m) of total surface flow, 31.504% (224268 ha-m) of total soil moisture storage, 30.826% (219442 ha-m) of total soil moisture and 18.451% (63444 ha-m) of total ground water. Part of rainfall as recharge enriches ground water and it is 12.5 % (199987 ha-m). There is movement to ground water from streams and flood flows which is - 4.851 % (-35079 ha-m) of total surface flow. The total utilizable surface and ground water for the ACZ IV computed as 460460 ha-m.

The soil moisture increases due to rainfall as well as from irrigation. 41.3% of rainfall and 7.067% of total surface flow is considered as soil moisture storage. Total zonal soil moisture storage is 711872 ha-m and out of this 268184 ha-m is available as ET for the crops.

Utilization of water takes place in four major categories. These are, domestic and animal water needs, crop water requirement and requirement of water for industrial and recreation. A water need of different sectors in districts of ACZ IV is presented in Fig. 26. Total crop water requirement of the zone is 490886 ha m. In comparison to the crop water demand the water demand towards domestic and animal husbandry is very low as it is respectively 11496 ha-m and 8844 ha-m. The industrial demand is computed as 6% of available water thus total zonal demand comes out as 79129 ha-m.

Total water needs and supply of different districts of ACZ IV is presented in Fig. 27. The excess of water is also shown in the figure. The water available for utilization at zonal level is 728644 ha-m. As for as the excess water concerns the zone has 163331 ha-m of surplus water and this is 29 % of total utilization. Considering net sown area as 623303 ha the average depth of excess water available per hectare is 26 cm. At district level the per unit hectare water availability in Hoshangabad is 34 cm while it is 18 cm in Narsinghpur district. It means, the future plans to enhance crop production or alternate cropping may be based on this much depth of water. An abstract in pictorial form is provided in Fig 28.

Table 16 : Water budgeting of Central Narmada valley, ha-m				
S.N	Particulars	Hoshangabad	Narsinghpur	Zone Total
1	Normal rainfall, ha-m	961374	638519	1599893
2	Immediate evaporation (17.5%)	168240	111741	279981
3	Surface flow (28.7%)	275914	183255	459169
4	From outside state(10.549% of total surface flow)	45838	30444	76282
5	To GW from flood flows (-4.851% of total surface flow)	-21079	-14000	-35079
6	From GW to surface flow(23.739% of total surface flow)	103151	68510	171661
7	From irrigated area to surface flow(7.067% of total surface flow)	30708	20395	51103
8	Total surface flow(45.198% of total ppt)	434522	288598	723120
9	Evaporation losses from reservoirs and tanks (7.916% of total surface flow)	34397	22845	57242
10	Flow into seas and outside state (43.445% of total surface flow)	188778	125381	314159
11	Utilizable surface flow (48.639% of total surface flow)	211347	140371	351718
12	Water available for ground water storage (12.5%)	120172	79815	199987
13	From streams and flood flows to GW(4.851% of total surface flow)	21079	14000	35079
14	From irrigation to GW addition (S.N.15-(12+13))	65368	43416	108784
15	Total GW (21.492% of total ppt)	206619	137231	343849
16	Evaporation and rise of water table (18.451% of total GW)	38123	25320	63444
17	Regeneration into streams(49.924% of total GW)	103152	68511	171663
18	GW available utilization(31.625% of total GW)	65343	43399	108742
19	Total utilizable surface + GW (S.N. 11+18)	276690	183770	460460
20	Soil moisture storage (41.3% of normal rainfall)	397047	263708	660756
23	Evaporation losses from soil moisture (31.504% of total soil moisture storage)	134763	89506	224268
24	Evap. losses from forest and other veg. (30.826% of total soil moisture)	131862	87579	219442
25	Soil moisture available for ET from crops (37.673 % of total soil moisture)	161151	107032	268184
26	Water requirement of crops	291921	198966	490887
27	Water requirement of animal husbandry	4407	4436	8843
28	Domestic water requirement	6115	5381	11496
29	Industrial Water requirement @ 6 % of available fresh water	48876	30253	79129
30	Water available for utilization (S.N. 19+25)	437841	290803	728644
31	Water required for different sectors (26+27+28+29)	351319	239036	590355
32	Surplus or deficit of water in the district (30-31)	86522	51767	138289

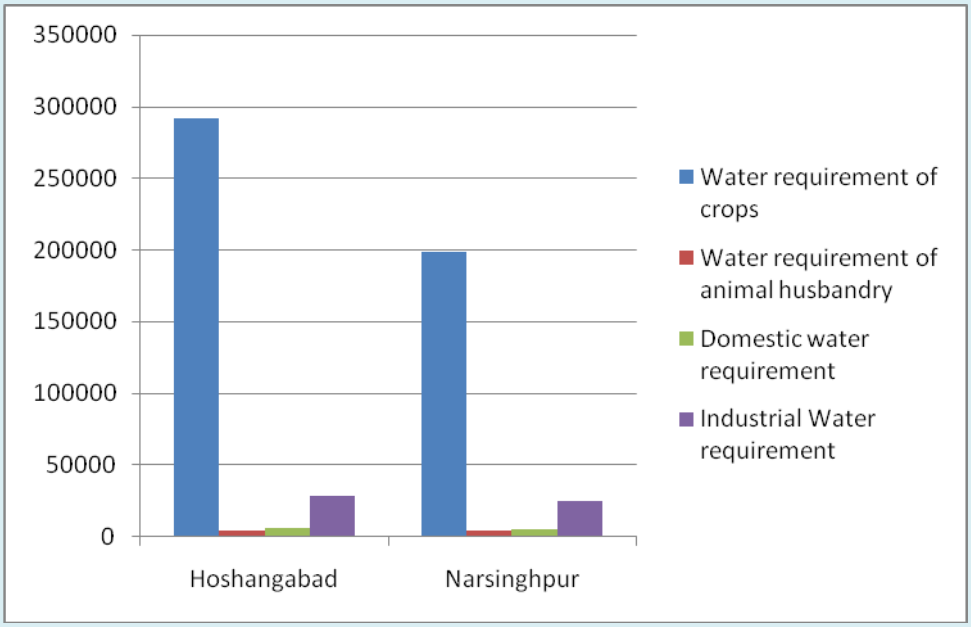


Fig. 26 Water needs of different sectors in districts of ACZ IV - Central Narmada Valley (ha-m)

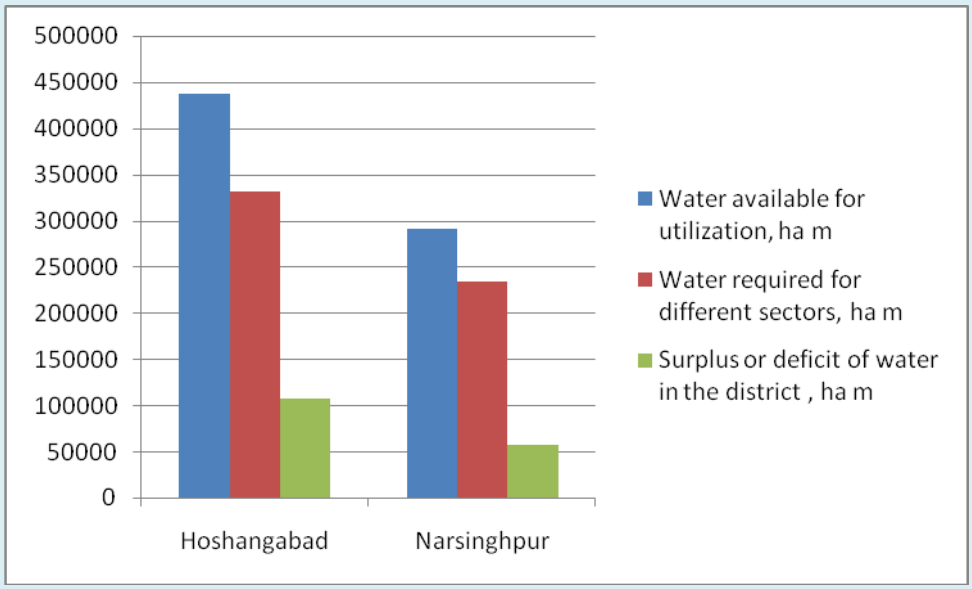


Fig. 27 Total Water needs and supply of different districts of ACZ IV - Central Narmada Valley (ha-m)

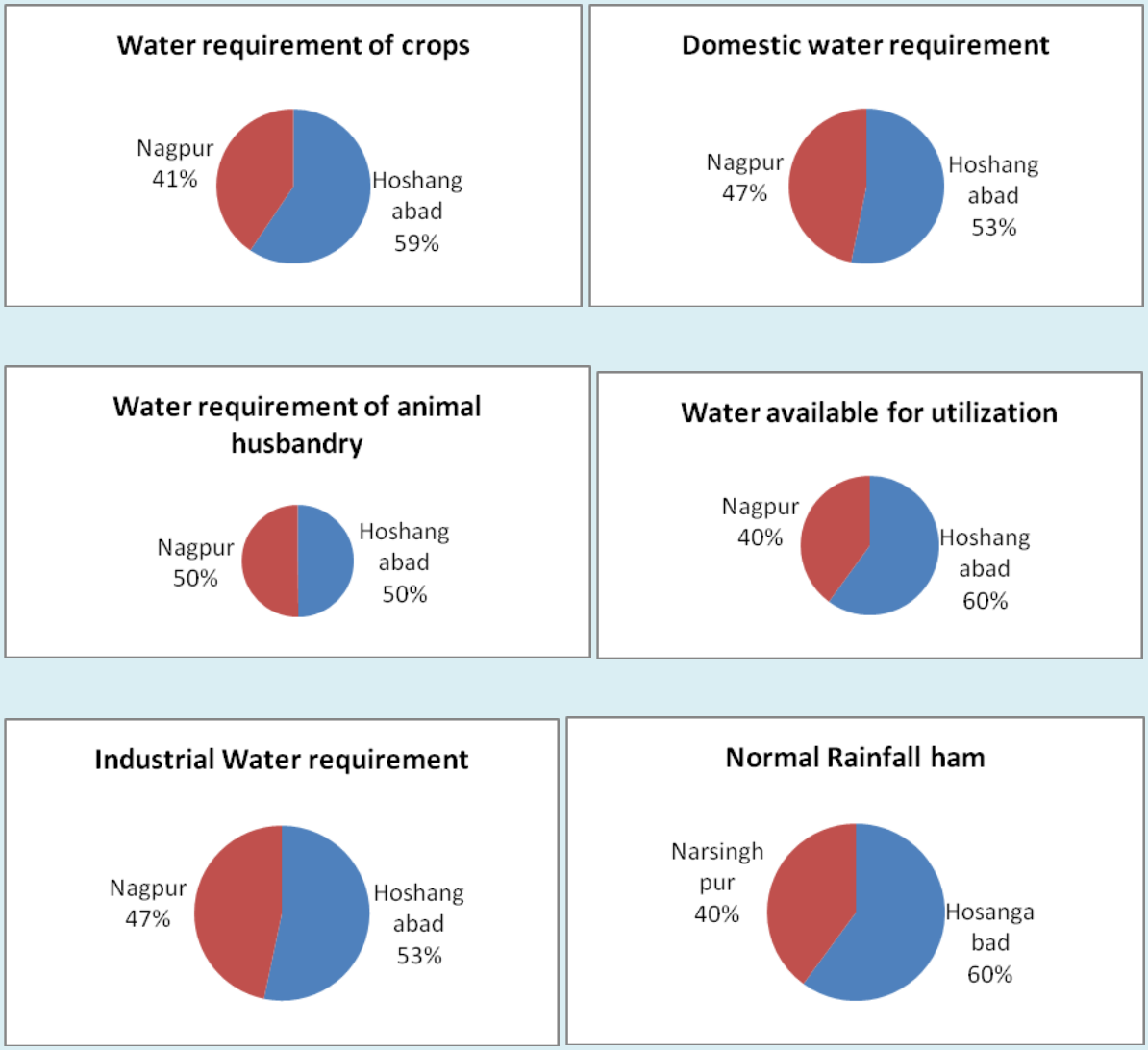


Fig. 28 Abstract of water of different districts of ACZ IV - Central Narmada Valley (ha-m)

Agroclimatic Zone V - Vindhya Plateau

The Agroclimatic zone V – Vindhya Plateau covers seven districts namely Bhopal, Damoh, Guna, Raisen, Sagar, Sehore and Vidisha. It comes under Wheat zone having medium black and deep black (medium/heavy) soils. The zone has total geographical area of 4895299 ha, out of which forest area is 27.1 % mostly in Damoh, Raisen and Sagar totaling 67.8 %. Net area sown is 55.7% in which Sagar and Vidisha has 39.7 % area. Out of total Net Sown area of 2727689 ha, the fallow land including current fallow is 1.4 %. District wise land utilization is presented in Table 17.

Rainfall analysis

Annual rainfall ranges from 1200 to 1400 mm. On an average 92 % of this rainfall occurs during monsoon i.e. June to September, 6% in winter i.e. late December and 2% in summer. Maximum rainfall occurs in the month of August followed by month July. The patterns of annual rainfall occurred in different districts of Agroclimatic zone V for years 1970 to 2014 are presented through Figures 29A-F. Mean annual rainfall of these districts are 1079.6 mm, 1170.4 mm, 855.0 mm, 1237.6 mm, 1197.6 mm, 1261.0 mm and 996.3 mm respectively Bhopal, Damoh, Guna, Raisen, Sagar, Sehore and Vidisha. The record also shows maximum ever rainfall of 2453 mm (1973) was occurred in Sagar. Rainfall of about 2000 mm was also occurred once in Damoh (2013), Vidisha (2013), Sehore (1973) and twice in Sagar (1999, 2013) in the year.

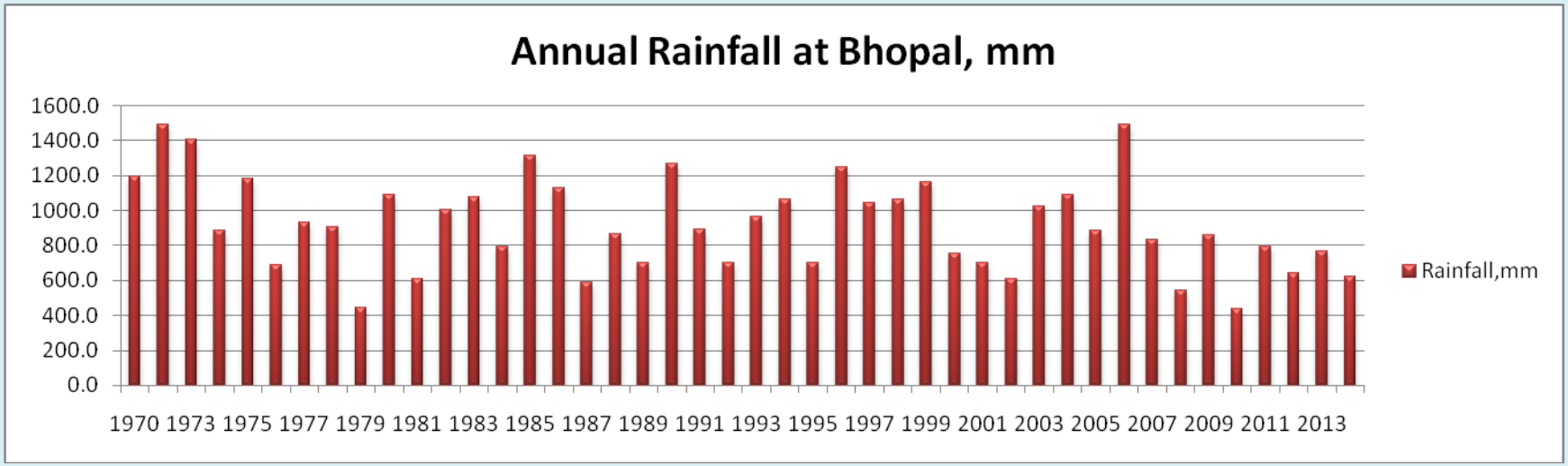
Domestic and livestock water needs

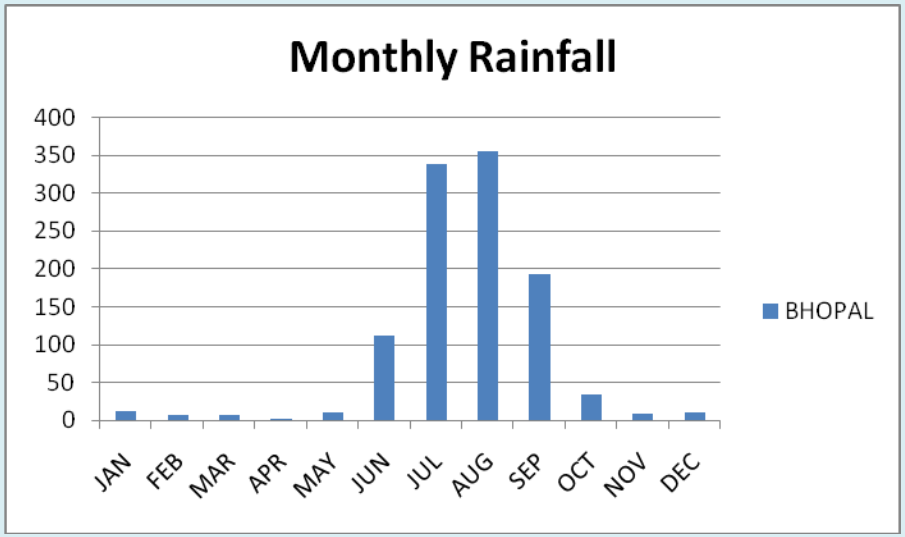
Total human population of the zone is 11352000 as per Census 2011. Total human water needs of the zone is 55937 ha m where the Bhopal and Sagar together consume 41.5% of zonal requirement followed by Vidisha (12.8%). The domestic need of rest of the districts is more or less the same amount of water i.e. about 11.5%. Table 18 illustrates water requirement towards human needs as well as for live stock. Live stock population comprises of cattle both cross breed and indigenous, buffalo, bovine, sheep, goat, horses and ponnies, mules, donkey, pigs, dogs, rabbits, fowls, ducks, turkey and other poultry. The indigenous cattles are about 22 times more than the cross breed cattles.

Table 17 Total Area and Classification of Area In Each District of Vindhya Plateau MADHYAPRADESH State for the year ending 2013-14															
DISTRICT NAME	Reporting Area For Land Utilization Statics			Not Available For Cultivation			Other Uncultivated Land Excluding Fallow Land			Fallow Land		Total	Net Area Sown	Total Cropped Area	Area Sown more than once
		Forests	Area Under Non Agricultural Uses	Barren and Unculturable Land	Total	Permanent Pastures and Other Grazing Lands	Land Under Misc Tree crops and Groves not Included in Net Area	Culturable Waste Land	Total	Fallow Lands Other than Current Fallows	Current Fallows				
(1)	(2)	(3)	(4)	(5)	6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
BHOPAL	277880	44106	33383	3949	37332	30235	30	5300	35565	4366	1120	5486	155391	247552	92161
DAMOH	728583	267536	32089	57489	89578	36338	258	9977	46573	4214	2711	6925	317971	519135	201164
GUNA	630766	101375	34898	62703	97601	30158	60	60624	90782	1215	776	1991	339017	524466	185449
RAISEN	848746	333672	40089	3620	43709	26041	109	7850	34000	2028	1245	3273	434092	719472	285380
SAGAR	1022759	297932	58326	12622	70948	76643	745	10572	87960	9949	7230	17179	548740	887288	338548
SEHORE	656368	172413	42292	9535	51827	26784	28	5521	32333	774	154	928	398867	760512	361645
VIDISHA	730197	109615	41940	9202	51142	23795	228	8166	32189	2377	1263	3640	533611	919277	385666
Total	**4895299**	**1326649**	**283017**	**159120**	**442137**	**249994**	**1398**	**108010**	**359402**	**24923**	**14499**	**39422**	**2727689**	**4577702**	**1850013**

Table 18 : Live stock and Human water needs of ACZ V								
	Bhopal	Damoh	Guna	Raisen	Sagar	Sehore	Vidisha	Zone Total
Cross breed Cattle	20658	4868	14824	12936	8073	51522	13026	125907
Water Req. (l/day)	3098700	730200	2223600	1940400	1210950	7728300	1953900	18886050
Indigenous Cattle	89434	553977	352976	417270	794747	205100	351331	2764835
Water Req. (l/day)	8943400	55397700	35297600	41727000	79474700	20510000	35133100	276483500
Buffalo	83655	106723	222426	118116	213711	133069	152480	1030180
Water Req. (l/day)	12548250	16008450	33363900	17717400	32056650	19960350	22872000	154527000
Bovine	193747	665568	590226	548322	1016531	389691	516837	3920922
Water Req. (l/day)	29062050	99835200	88533900	82248300	152479650	58453650	77525550	588138300
Sheep	65	3627	706	850	1327	175	511	7261
Water Req. (l/day)	650	36270	7060	8500	13270	1750	5110	72610
Goat	39155	121823	129993	90778	140628	67971	80598	670946
Water Req. (l/day)	391550	1218230	1299930	907780	1406280	679710	805980	6709460
Horse & Ponies	66	246	94	277	450	54	353	1540
Water Req. (l/day)	2145	7995	3055	9002.5	14625	1755	11472.5	50050
Mules	0	0	18	4	39	9	213	283
Water Req. (l/day)	0	0	585	130	1267.5	292.5	6922.5	9197.5
Donkey	181	50	615	322	45	91	518	1822
Water Req. (l/day)	5882.5	1625	19987.5	10465	1462.5	2957.5	16835	59215
Camels	0	0	52	1	5	2	0	60

Water Req. (l/day)	0	0	5980	115	575	230	0	6900
Pigs	945	5418	3415	1010	5837	686	2411	19722
Water Req. (l/day)	9450	54180	34150	10100	58370	6860	24110	197220
Dogs	7410	9112	9528	13691	18413	2010	7466	67630
Water Req. (l/day)	37050	45560	47640	68455	92065	10050	37330	338150
Rabbits	210	12	114	148	39	13	63	599
Water Req. (l/day)	134.4	7.68	72.96	94.72	24.96	8.32	40.32	383.36
Elephants	9	0	0	0	7	3	0	19
Water Req. (l/day)	1350	0	0	0	1050	450	0	2850
Fowls	26635	37723	44107	50730	75504	40469	24467	299635
Water Req. (l/day)	6658.75	9430.75	11026.75	12682.5	18876	10117.25	6116.75	74908.75
Ducks	100	17	87	232	161	8	47	652
Water Req. (l/day)	25	4.25	21.75	58	40.25	2	11.75	163
Turkeys	15	0	25	2	0	0	0	42
Water Req. (l/day)	3.75	0	6.25	0.5	0	0	0	10.5
Other Poultry	5	0	25	2	3	0	36	71
Water Req. (l/day)	1.25	0	6.25	0.5	0.75	0	9	17.75
TWR lpd	54569591	174854017	162217752	145915175	269105377	108257356	139548845	1054468112
TWR ha m	1975	6327	5871	5280	9739	3919	5051	38162
Human Population	2368145	1263703	1240938	1331699	2378295	1311008	1458212	11352000
TWR human, ha-m	11669	6227	6115	6562	11719	6460	7185	55937





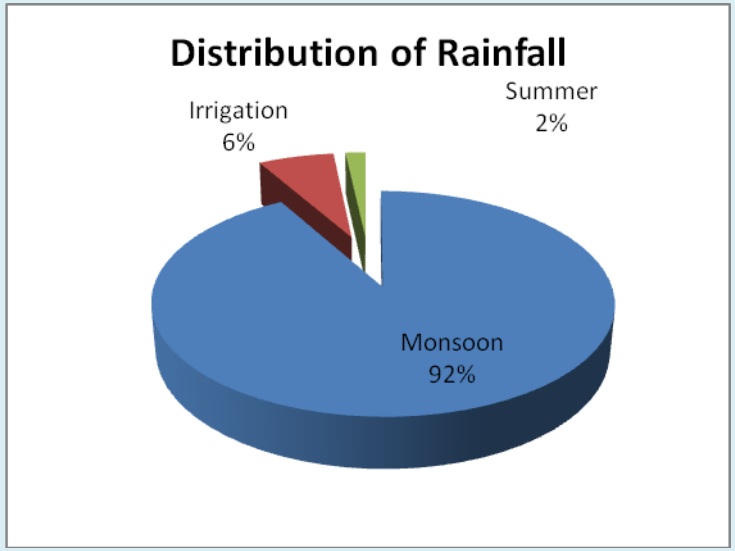
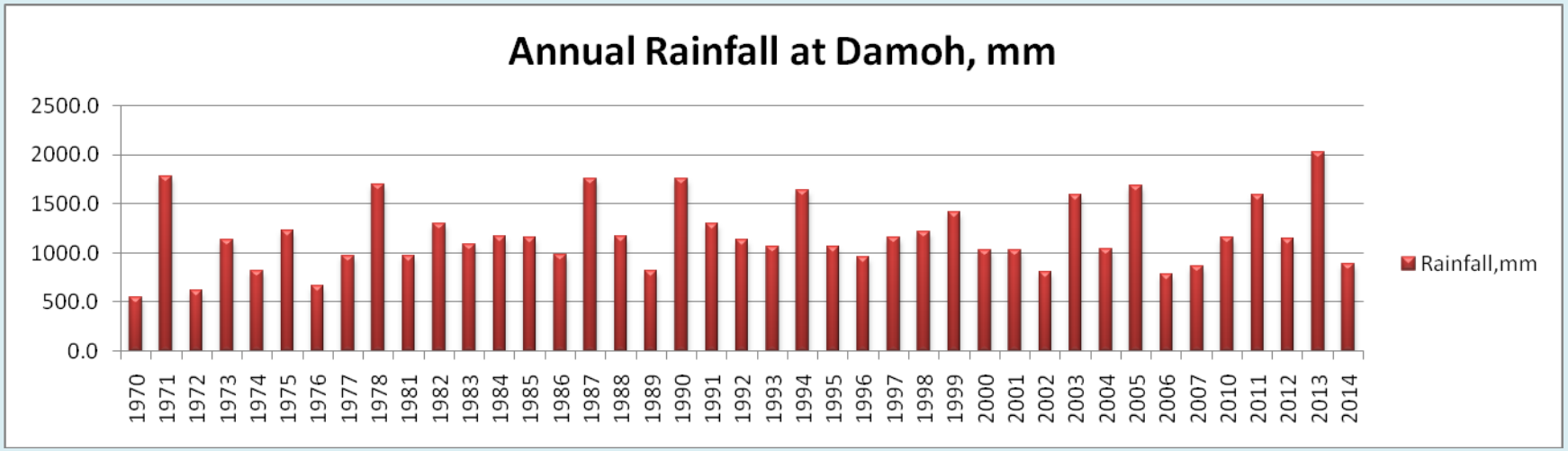
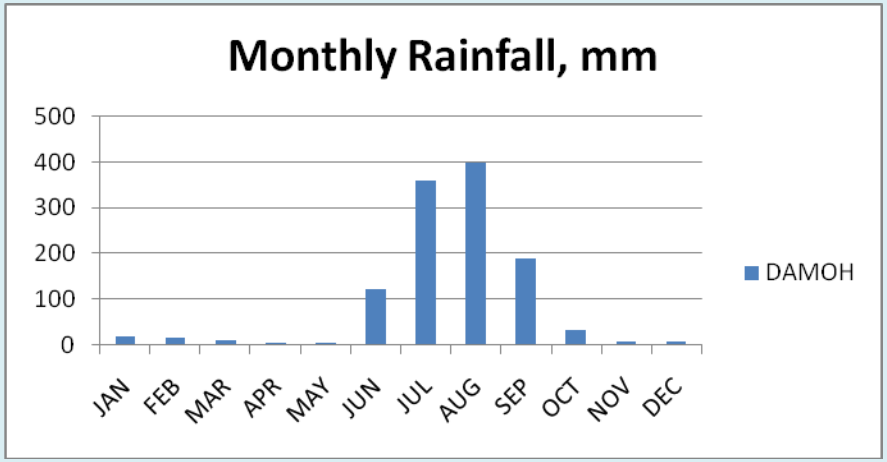


Fig. 29A Rainfall analysis at district Bhopal, Agro-Climatic Zone –V, Vindhaya Plateau





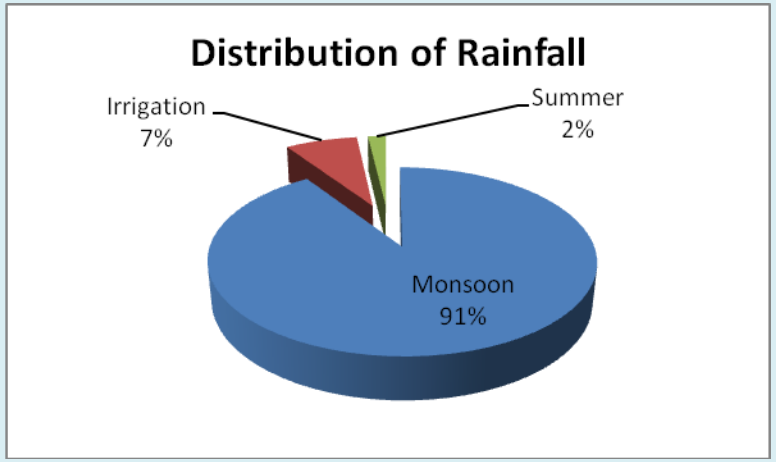
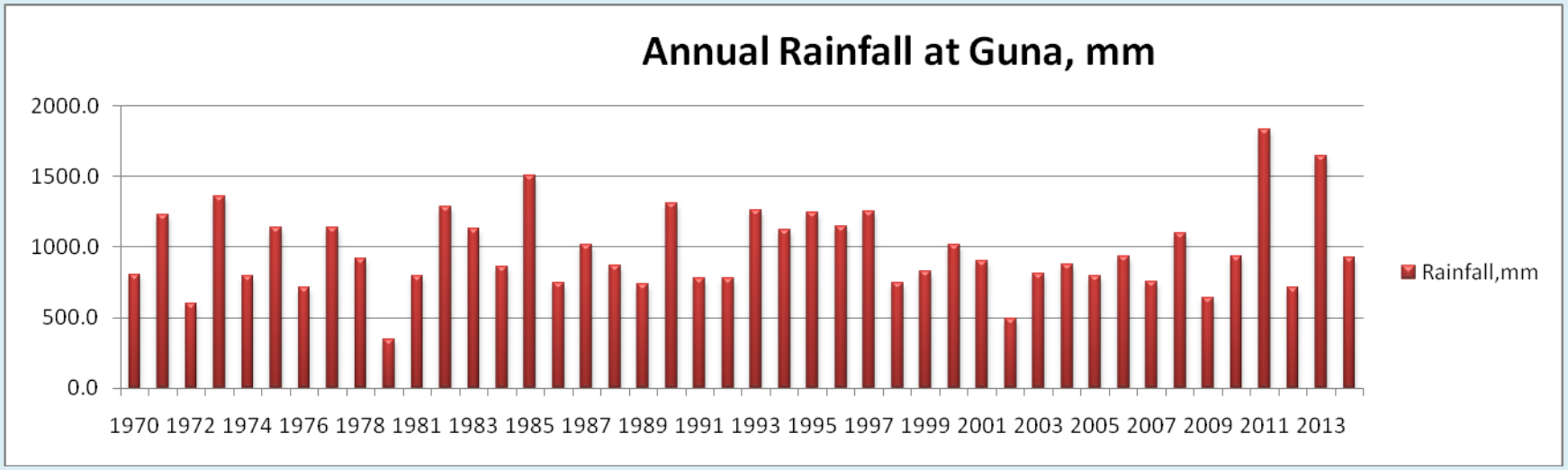
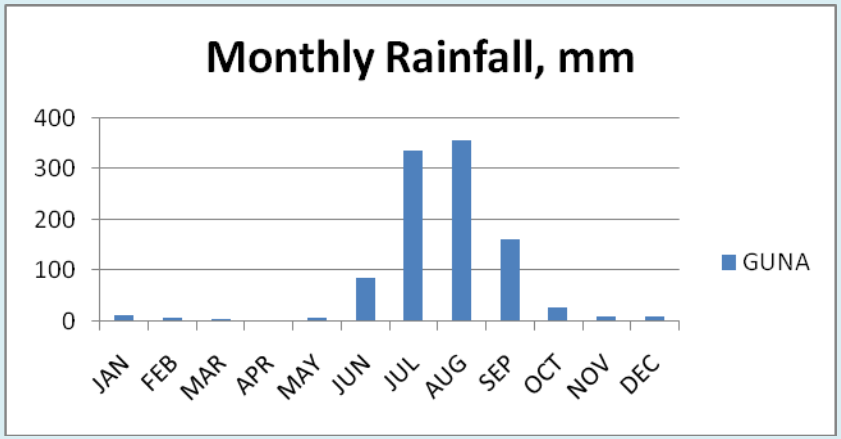


Fig. 29B Rainfall analysis at district Damoh, Agro-Climatic Zone –V, Vindhaya Plateau





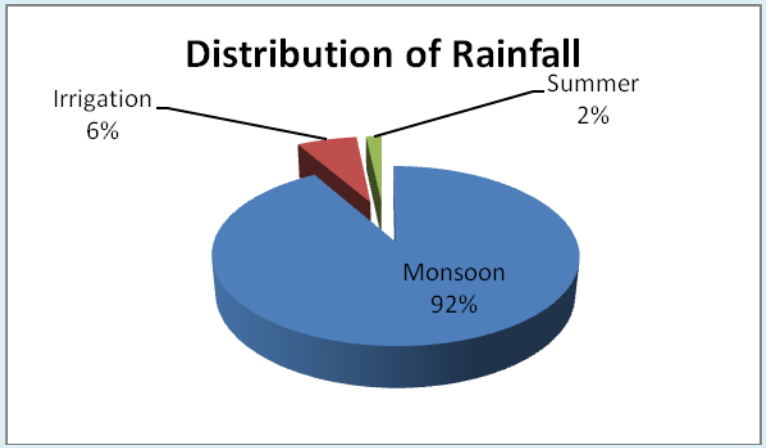
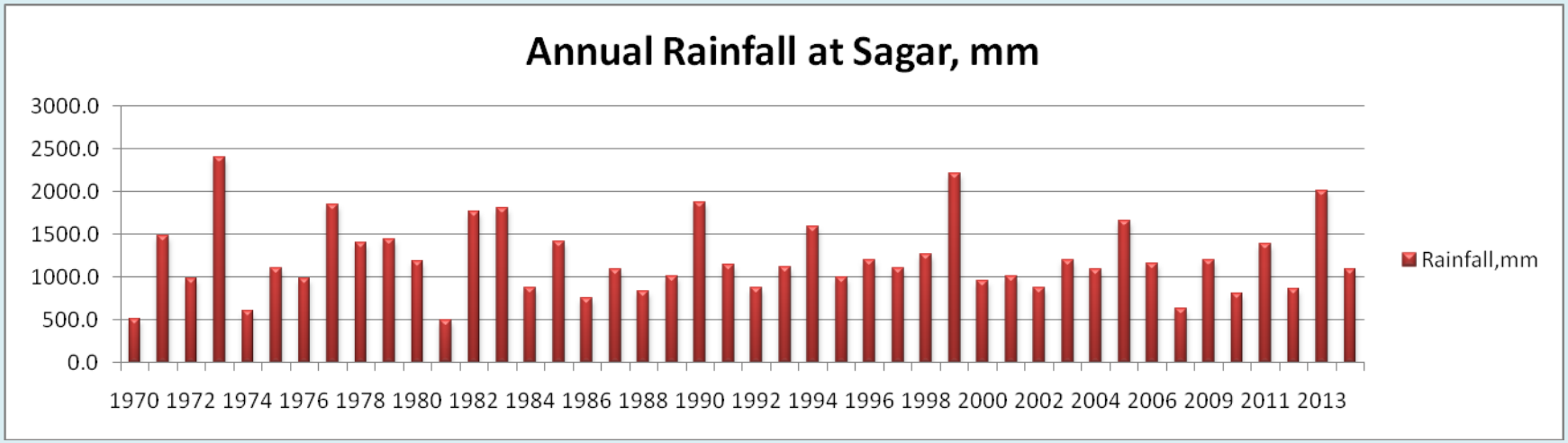
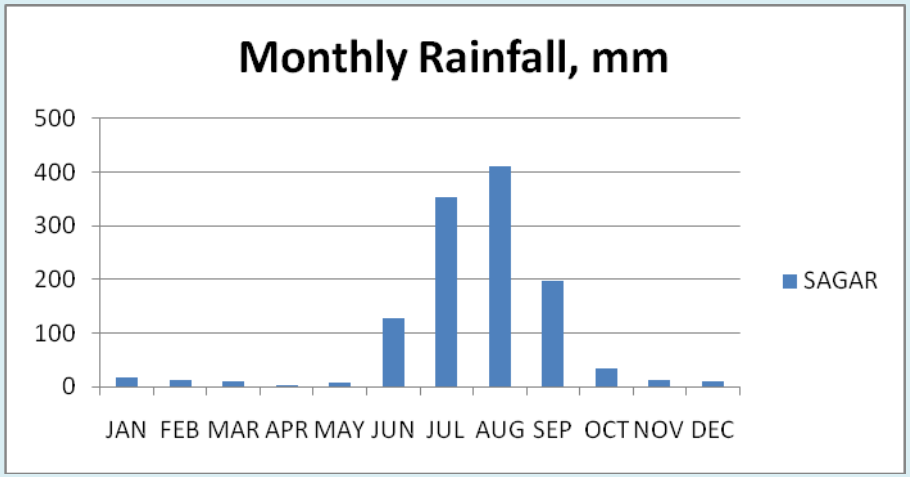


Fig. 29C Rainfall analysis at district Guna, Agro-Climatic Zone –V, Vindhaya Plateau





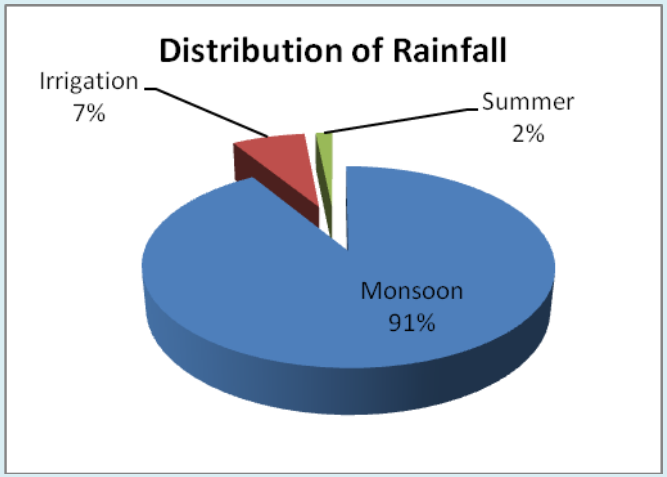
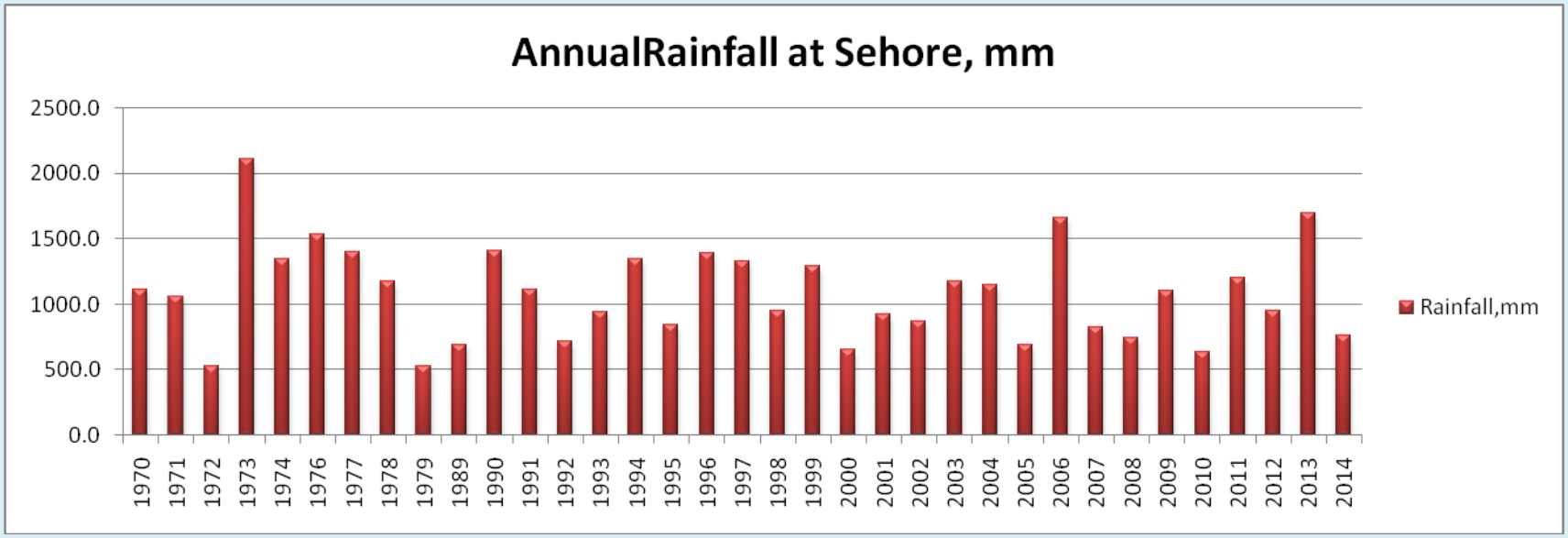
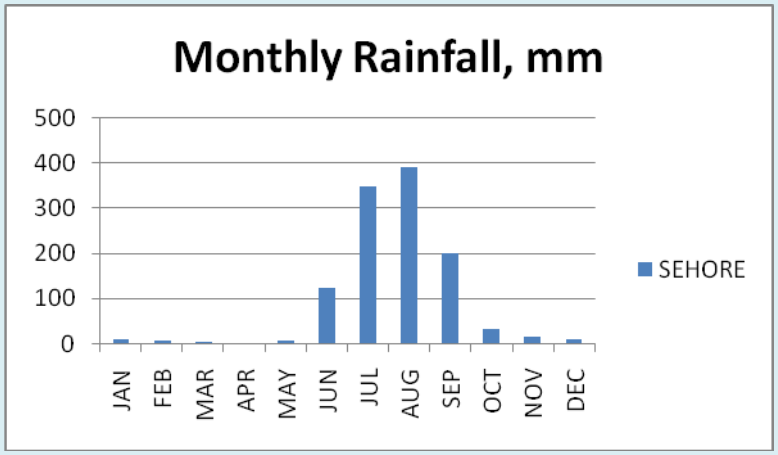


Fig. 29D Rainfall analysis at district Sagar, Agro-Climatic Zone –V, Vindhaya Plateau





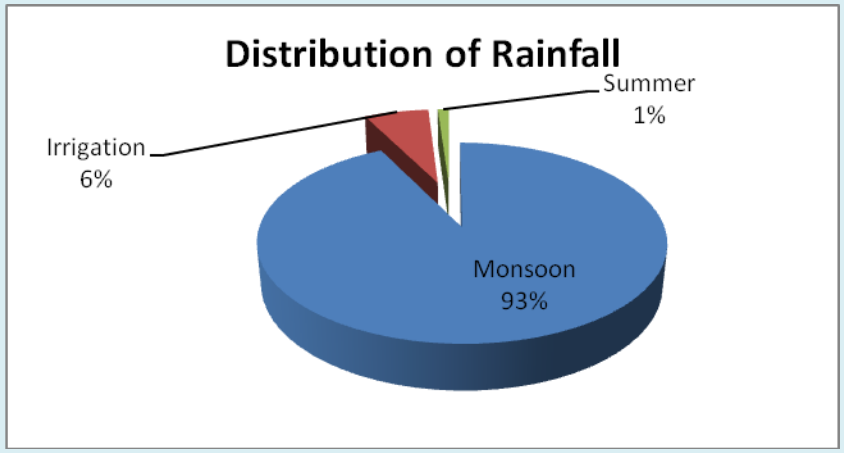
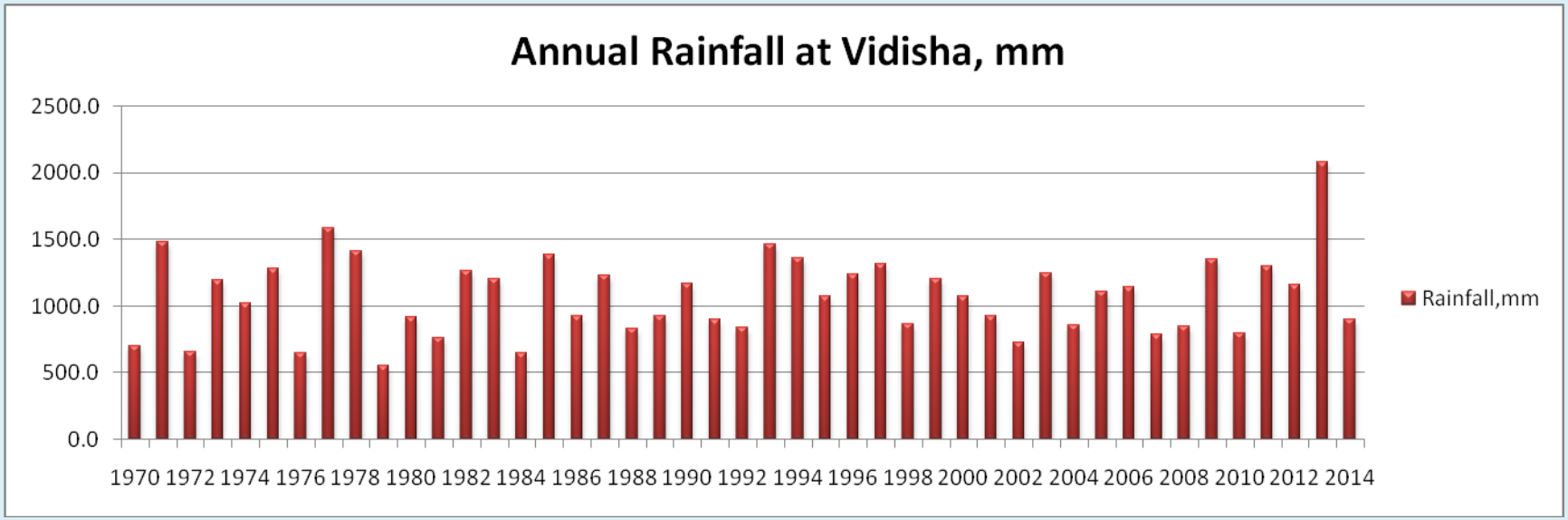
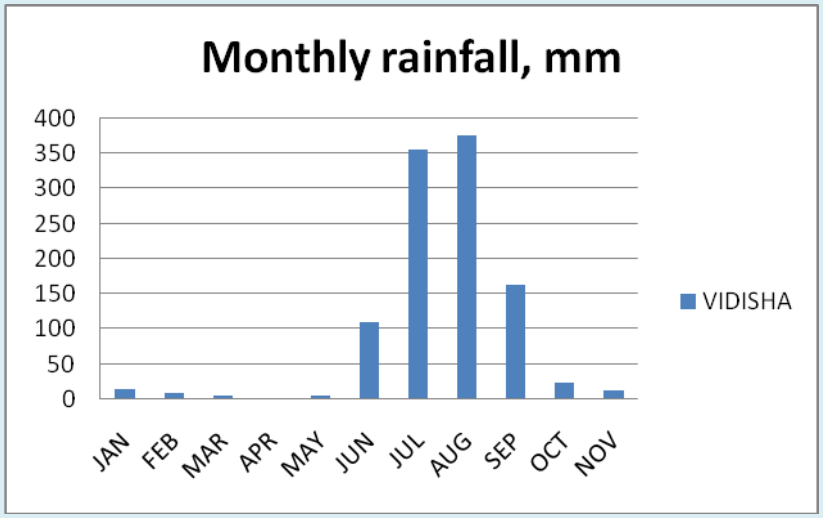


Fig. 29E Rainfall analysis at district Sehore, Agro-Climatic Zone –V, Vindhaya Plateau





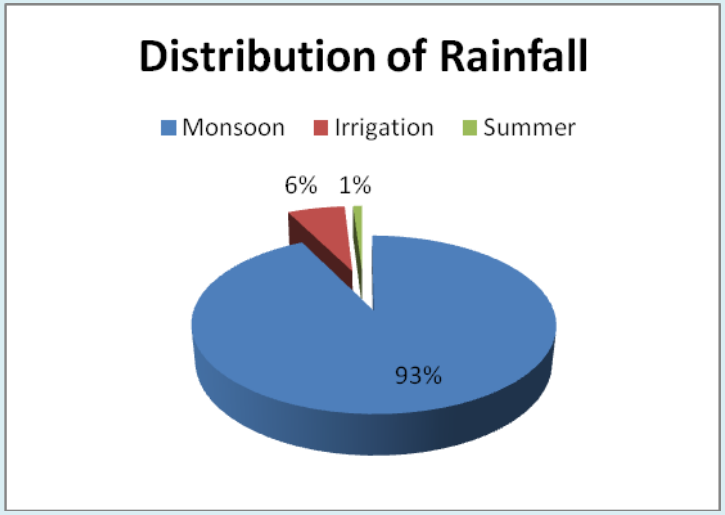


Fig. 29F Rainfall analysis at district Vidisha, Agro-Climatic Zone –V, Vindhaya Plateau

In Sehore the cross breed cattles are 25.1% of its indigenous cattles whereas this percentage is 23.1 % in Bhopal district. All other districts have less than 4 % of its cattles as cross breed. This indicates that the zone has tremendous scope for breeding improvement programmes. As usual bovine (3920922) is the main cattle class found in the zone in which Sagar has maximum than other districts with bovine population of 1016531 (25.9%). Bhopal is having the least bovine population (4.9%). Total bovine population of the zone is about four times more than the buffalo population. Guna and Sagar dominates in buffalo population with zonal percentage of 42.3%. The goat is mostly populated in Damoh, Guna and Sagar with 58.5 zonal percentages. Maximum numbers of fowls are found in Sagar (75504) which is 25.2% of the zone. Other common animals of the zone are dogs (67630) and pigs (19722). Total live stock water needs of the zone comes out 38163 ha m. It is maximumin in Sagar (28.5%) followed by Damoh (16.6%), Guna (15.4%), Raisen (13.8%), Vidisha (13.2%), Sehore (10.3%) and Bhopal (5.2%).

Water requirement of crops

The zone is a Wheat zone has 1271753 ha under wheat in which Raisen, Sagar, sehore and Vidisha aggregates 76.8%. Gram is also taken in larger area as it is sown in 1178002 ha in which Damoh, Raisen, Sagar and Vidisha contributes in 60.4 % area. Pigeon pea is taken in 48506 ha, mostly in Raisen (28.0%). Guna has neglizible area of 2.1% in Pigeonpea cultivation category. Other pulses (rabi) occupies an area of 201144 ha in which Sagar and Vidisha together contributes 55.8% of total cultivation of other pulses (rabi). Area under other pulses (kharif) is 115718 ha mostly confined in Vidisha (46.3%) followed by Sagar (23.0%) and Damoh (22.8%). Percentage area under maize is 38.2% while total area under maize in the zone is 40681 ha. Soyabean is taken in 1666289 ha in the zone and Sagar, Sehore and Vidisha are the main contributors with 58.9 % area of soybean under these districts Table 19A-B. Based on growing period, crop coefficient values, the water requirement of all the crops were worked out and presented in Table3. Total yearly water requirement of the crops of the zone is 11707069 ha-m. The major user of water, in terms of crop water requirement, is Sagar district (18.9%) followed by Vidisha (18.3%), Sehore (17.4%), Raisen(16.4%), Guna (12.2%), Damoh (11.3%) and Bhopal (5.3%). Figure 30-32 depicts crop water requirement of major crops in the districts of the zone.

Table 19 A : Water requirement of field crops in Vindhya Plateau, ha m

	Bhopal		Damoh		Guna		Raisen		Sagar		Sehore		Vidisha	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Rice	522	387	55634	40557	512	409	62686	47704	4776	3721	19660	14588	1500	1142
Jowar (Kharif)	26	12	319	144	2831	1444	44	22	784	383	1115	515	776	382
Jowar (Rabi)	-	-	4	2	-	-	-	-	-	-	-	-	-	-
Bajra	-	-	1	0	69	30	14	6	14	6	-	-	-	-
Maize	2223	1126	1681	830	15467	8651	3237	1747	2782	1492	8241	4175	7050	3805
Ragi	-	-	-	-	-	-	-	-	1	0	-	-	-	-
Wheat	84996	52420	88617	55953	120843	70186	241868	127352	228788	141940	245359	151321	261282	137574
Barley	-	-	140	84	8	4	20	10	707	419	16	9	227	114
Other Cereals and Millets (Kharif)	-	-	90	43	-	-	131	65	199	101	-	-	61	30
Other Cereals and Millets (Rabi)	-	-	7	4	-	-	-	-	205	113	-	-	20	9
Gram	28520	16190	178072	103491	79602	42555	155702	75461	181030	103377	100859	57255	197217	95581
Arhar (Tur)	1679	1006	8427	4990	993	623	13584	8016	5991	3723	8740	5236	9092	5365
Other Pulses (Rabi)	2663	1418	22172	12090	3722	1867	33713	15330	50537	27078	26528	14130	61809	28107
Other Pulses (Kharif)	486	227	26420	12134	4136	2079	3653	1751	26666	13087	708	331	53649	25721
Sugarcane	204	271	98	130	895	1217	753	973	478	656	1129	1501	180	233
Groundnut	318	166	93	47	85	49	171	95	1482	818	446	233	815	453
Castor seed	-	-	-	-	-	-	-	-	51	64	-	-	-	-
Sesamum	56	28	1203	592	235	127	59	30	1086	571	70	35	279	143
Rapeseed and Mustard	60	33	613	340	2108	1078	233	106	426	233	68	37	78	35
Linseed	16	9	182	106	-	-	294	142	823	470	103	58	113	55
Soyabean	114254	44262	128582	48559	247130	105698	194522	80289	351743	144267	312239	120961	317819	131180

Niger seed	-	-	-	-	-	-	-	-	1104	834	-	-	-	-
Sunflower	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Safflower	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Oilseeds	-	-	-	-	-	-	-	-	509	297	-	-	-	-
Cotton	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jute	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mesta	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sanhemp	5	4	-	-	-	-	-	-	19	16	26	21	2	2
Other Fibres	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 19 B : Water requirement of fruits and Vegetables crops in Vindhya Plateau, ha m

	Bhopal		Damoh		Guna		Raisen		Sagar		Sehore		Vidisha	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Chillies	220	242	368	408	18	20	124	131	399	448	371	407	70	74
Ginger	5	6	184	224	21	26	39	46	258	325	2	2	180	214
Turmeric	-	-	12	15	-	-	1	1	38	48	-	-	-	-
Betel nut	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Garlic	307	494	107	173	81	133	77	121	849	1412	1974	3178	12	19
Coriander	1470	2112	376	542	35656	51701	512	693	482	712	649	933	-	-
Other Condiments and Spices	13	16	15	19	4	5	5	6	33	42	199	248	-	-
Mango	56	90	-	-	10	16	16	25	2	3	22	35	25	39
Banana	-	-	-	-	-	-	-	-	2	4	-	-	-	-
Citrus Fruits	24	31	9	12	-	-	75	95	5	7	54	70	10	13
Grapes	-	-	-	-	-	-	-	-	-	-	-	-	6	6
Papaya	9	15	-	-	8	13	178	287	-	-	-	-	81	131
Other Fruits	7	11	104	168	14	23	4	6	91	151	39	63	129	204
Potato	66	62	981	950	216	199	198	168	2543	2443	413	391	243	206
Sweet Potato	-	-	97	64	55	40	49	34	80	56	37	25	40	27
Onion	696	1186	916	1566	257	447	558	932	4214	7422	2333	3977	176	294
Other Vegetables (Kharif)	952	636	1105	725	213	153	342	234	1231	863	657	439	397	272
Other Vegetables (Rabi)	1098	831	1479	1146	312	222	1584	1024	3382	2575	1863	1410	893	577
Opium	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tobacco	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other Plantation Crops	10	18	16	29	-	-	-	-	98	182	-	-	-	-
Fodder Crops	6449	4386	1003	670	8962	6556	5026	3506	13194	9422	26583	18081	3392	2366
Other Non Food Crops	142	184	6	8	-	-	-	-	123	164	9	12	-	-

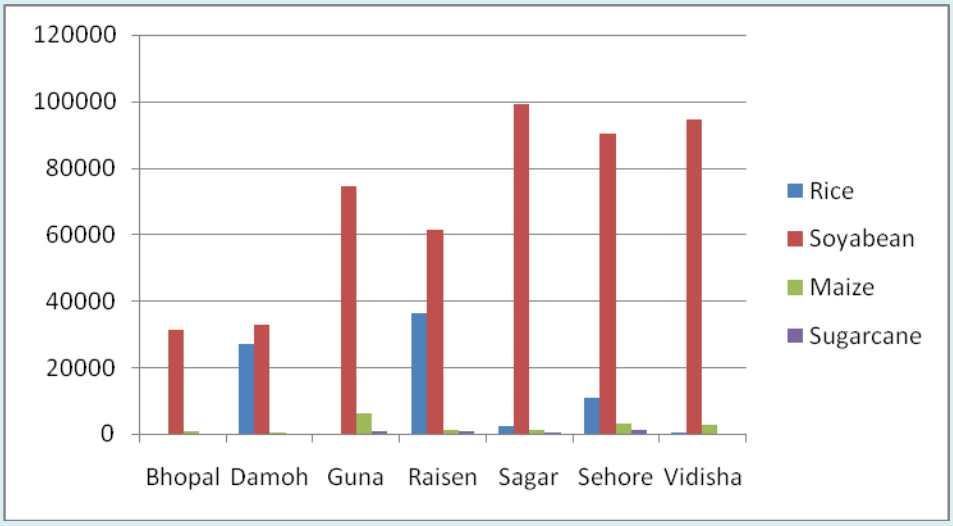


Fig. 30 Crop water requirement of major kharif crops of ACZ V-Vindhya Plateau in ha m

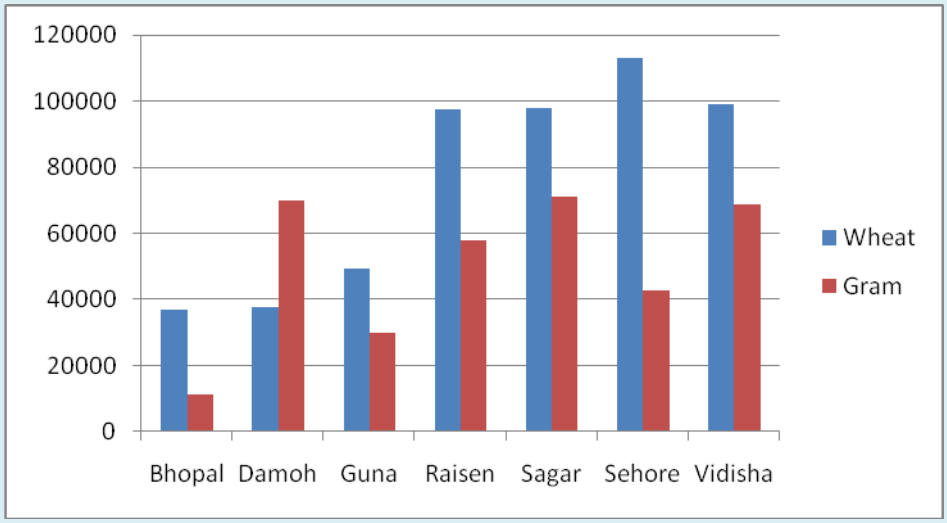


Fig. 31 Crop water requirement of major rabi crops of ACZ V-Vindhya Plateau in ha m

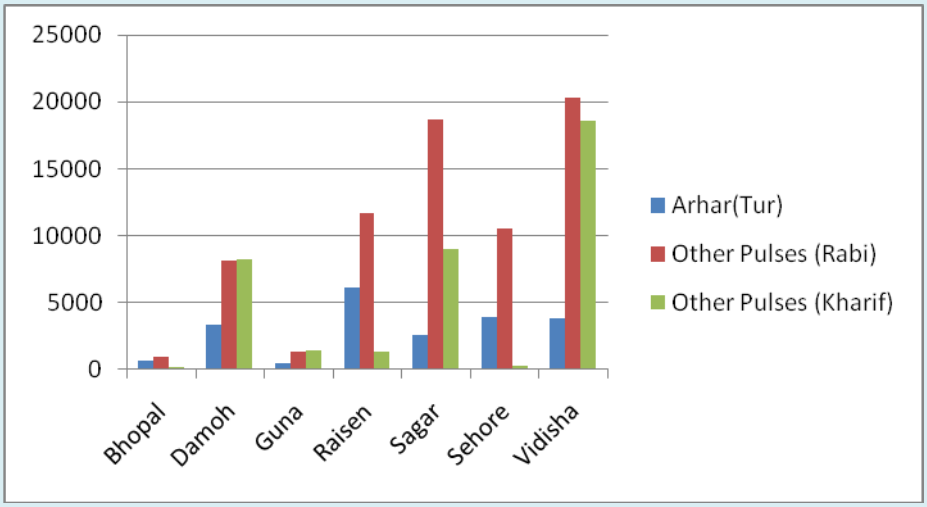


Fig. 32 Crop water requirement of pulse crops of ACZ V-Vindhya Plateau in ha m

Area under vegetables under different districts of the zone is presented in Table 19B. Coriander is taken in 39145 ha in the zone and almost total is taken in Guna district (91.1%). Potato is taken in 4660 ha and Sagar stood first (54.6%) in this crop. Sagar and Sehore together contribute 71.5% of onion cultivation. Acerage under other vegetables in Kharif and rabi is respectively 4897 ha and 10611 ha. In rabi the Sagar dominates in this category of crop (3382ha).

Water budget

Rainfall is the prime and sole input of water to any area. The agroclimatic zone V (ACZ V)- Vindhya Plateau receives total quantum of water towards rainfall as 5522476 ha-m and its magnitude is maximum in Sagar (22.2%), followed by Raisen (19.0%), Damoh (15.4%), Sehore (15.0%), Vidisha (13.2%), Guna (9.8%) and Bhopal (5.4%). National Commission on Agriculture has laid down norms for water budgeting of an area and as per its estimate the losses of water as evaporation, surface water flow and ground water flow out of the area is calculated in present estimation. Similarly, addition of water into the area as runoff generated from the zone, addition of soil moisture and to the ground water is also computed. The water budget so generated for ACZ-V is presented in Table 20. The immediate evaporation losses that occurs during the rainfall is taken as 17.5% of total rainfall and it is 966433 ha-m for the zone. 28.7% rainfall converts into surface flow and it is 1584951 ha-m. It is considered that 10.549 % (263308 ha-m) of surface flow goes out of the zone. Ground water also adds to the surface flow and it is taken as 23.739% of surface flow. Thus, surface flow arrives to be 2496049 ha-m which is 45.198% of total precipitation.

Evaporation takes place from open water body, soil surface, forest and vegetation and also from rise of water table, and, respectively it is taken as 7.916% (197587 ha-m) of total surface flow, 31.504% (774124 ha-m) of total soil moisture storage, 30.826% (757464 ha-m) of total soil moisture and 18.451% (218993 ha-m) of total ground water. Part of rainfall as recharge enriches ground water and it is 12.5 % (690310 ha-m). There is an addition to the ground water from streams and flood flows which is - 4.851 % (- 121083 ha-m) of total surface flow. The total utilizable surface and ground water for the ACZ V computed as 1589407 ha-m.

Table 20 : Water budgeting of Vindhya Plateau, ha-m

S. N	Particulars	Bhopal	Damoh	Guna	Raisen	Sagar	Sehore	Vidisha	Zone Total
1	Normal rainfall, ha-m	299999	852733	539305	1050408	1224856	827680	727495	5522476
2	Immediate evaporation (17.5%)	52500	149228	94378	183821	214350	144844	127312	966433
3	Surface flow(28.7%)	86100	244734	154781	301467	351534	237544	208791	1584951
4	From outside state(10.549% of total surface flow)	14304	40658	25714	50083	58400	39463	34687	263308
5	To GW from flood flows (-4.851% of total surface flow)	-6578	-18697	-11825	-23031	-26856	-18147	-15951	-121083
6	From GW to surface flow(23.739% of total surface flow)	32189	91494	57865	112704	131422	88806	78057	592537
7	From irrigated area to surface flow(7.067% of total surface flow)	9582	27238	17226	33552	39124	26437	23237	176396
8	Total surface flow(45.198% of total ppt)	135594	385418	243755	474763	553610	374095	328813	2496049
9	Evaporation losses from reservoirs and tanks (7.916% of total surface flow)	10734	30510	19296	37582	43824	29613	26029	197587
10	Flow into seas and outside state (43.445% of total surface flow)	58909	167445	105899	206261	240516	162525	142853	1084408
11	Utilizable surface flow (48.639% of total surface flow)	65951	187464	118560	230920	269271	181956	159931	1214053
12	Water available for ground water storage (12.5%)	37500	106592	67413	131301	153107	103460	90937	690310
13	From streams and flood flows to GW(4.851% of total surface flow)	6578	18697	11825	23031	26856	18147	15951	121083
14	From irrigation to GW addition (S.N.15-(12+13))	20398	57981	36670	71422	83283	56278	49466	375498
15	Total GW (21.492% of total ppt)	64476	183269	115907	225754	263246	177885	156353	1186891

16	Evaporation and rise of water table (18.451% of total GW)	11896	33815	21386	41654	48572	32822	28849	218993
17	Regeneration into streams(49.924% of total GW)	32189	91495	57866	112705	131423	88807	78058	592543
18	GW available utilization(31.625% of total GW)	20390	57959	36656	71395	83252	56256	49447	375354
19	Total utilizable surface + GW (S.N. 11+18)	86342	245423	155216	302315	352522	238212	209378	1589407
20	Soil moisture storage (41.3% of normal rainfall)	123900	352179	222733	433819	505866	341832	300455	2280783
21	From irrigated area to soil moisture(7.067% of total surface flow)	9582	27238	17226	33552	39124	26437	23237	176396
22	Total soil moisture storage (44.495% of total ppt)	133485	379424	239964	467379	545000	368276	323699	2457226
23	Evaporation losses from soil moisture (31.504% of total soil moisture storage)	42053	119534	75598	147243	171697	116022	101978	774124
24	Evap. losses from forest and other veg. (30.826% of total soil moisture)	41148	116961	73971	144074	168002	113525	99783	757464
25	Soil moisture available for ET from crops (37.673 % of total soil moisture)	50288	142940	90402	176076	205318	138741	121947	925711
26	Water requirement of crops	90430	193633	207925	280296	323467	298223	313096	1707070
27	Water requirement of animal husbandry	1975	6327	5871	5280	9739	3919	5051	38162
28	Domestic water requirement	11699	6227	6115	6562	11719	6460	7185	55967
29	Industrial Water requirement @ 6 % of available fresh water	16977	45636	27010	55554	68136	40870	50237	304420
30	Water available for utilization (S.N. 19+25)	136629	388363	245617	478390	557840	376953	331325	2515118
31	Water required for different sectors (26+27+28+29)	121081	251823	246921	347692	413061	349472	375569	2105619
32	Surplus or deficit of water in the district (30-31)	15548	136540	-1304	130698	144779	27481	-44244	409499

The soil moisture increases due to rainfall as well as from irrigation. 41.3% of rainfall and 7.067% of total surface flow is considered as soil moisture storage. Total zonal soil moisture storage is 2457226 ha-m and out of this 925711 ha-m is available as ET for the crops. Each and every district of the ACZ V zone contributes in same proportion in zonal water budgeting as the quantum of rainfall of each district contributes in zonal rainfall quantum owing to rainfall based water distribution.

Utilization of water takes place in four major categories. These are, domestic and animal water needs, crop water requirement and requirement of water for industrial and recreation. A water need of different sectors in districts of ACZ V is presented in Fig. 33. Total crop water requirement of the zone is 1707069 ha-m and out of which Raisen, Sagar, Sehore and Vidisha needs 71.2% of zonal crop water need. The least crop water demand comes from Bhopal with 5.3%. In comparison to the crop water demand the water demand towards domestic and animal husbandry is very low as it is respectively 55937 ha-m and 38163 ha-m. Owing to higher population in Bhopal and Sagar the domestic demand is about 41.8% of the zonal demand. Guna registers the least domestic water demand i.e. only 10.9%. Sagar has more animal population and r needs 25.5% of zonal total. The industrial demand is computed as 6% of available water thus total zonal demand comes out as 304424 ha-m.

Total water needs and supply of different districts of ACZ V is presented in Fig 34. The excess/deficit of water is also shown in the figure. The water available for utilization at zonal level is 2515118 ha m. Sagar has the maximum (22.2%) water available for utilization followed by Raisen (19.0%), Damoh (15.4%), Sehore (15.0%), Vidisha (13.2%), Guna (9.8%) and Bhopal (5.4%). The total zonal water demand is 2025157 ha-m which gives an excess of 489961 ha-m at zonal level. One districts Vidisha has water in deficit (-5%). Guna is neighter excess nor deficit water while Bhopal and Sehore both have very little i.e. respectively 3% and 5%. Only Damoh and Sagar have sufficient excess of water.. An abstract in pictorial form is provided in Fig 35.

Taking net sown area of these district, as per Directorate of Extension and Farmers Welfare, 155391 ha, 317971 ha, 339017 ha, 434092 ha, 548740 ha, 398867 ha and 533611 ha , the per hectare water excess/deficit comes out to be 2 cm, 49 cm, 0 cm, 36 cm, 32 cm, 4 cm and -3 cm. It means, the future plans to enhance crop production or alternate cropping may be based on this much depth of water.

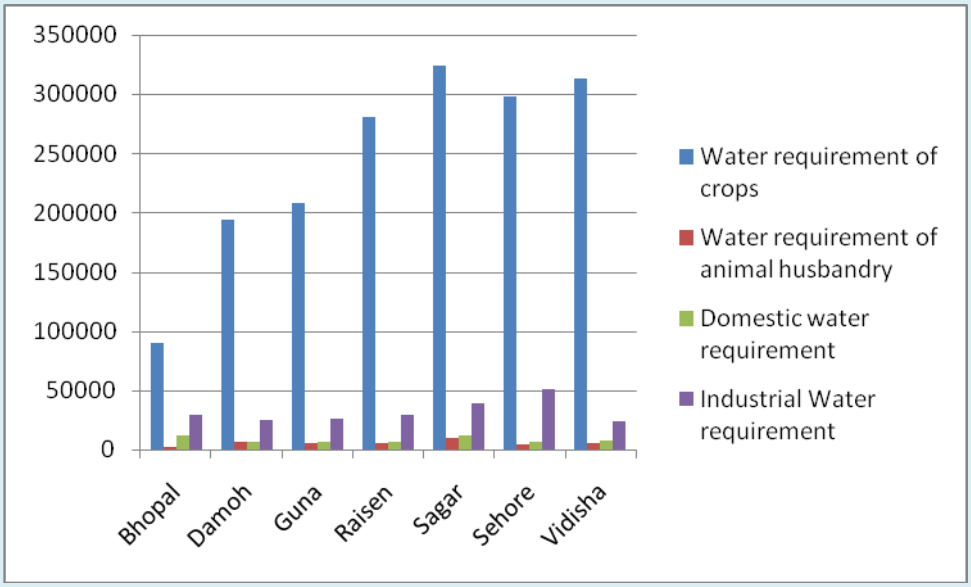


Fig. 33 Water needs of different sectors in districts of ACZ V - Vindhya Plateau (ha-m)

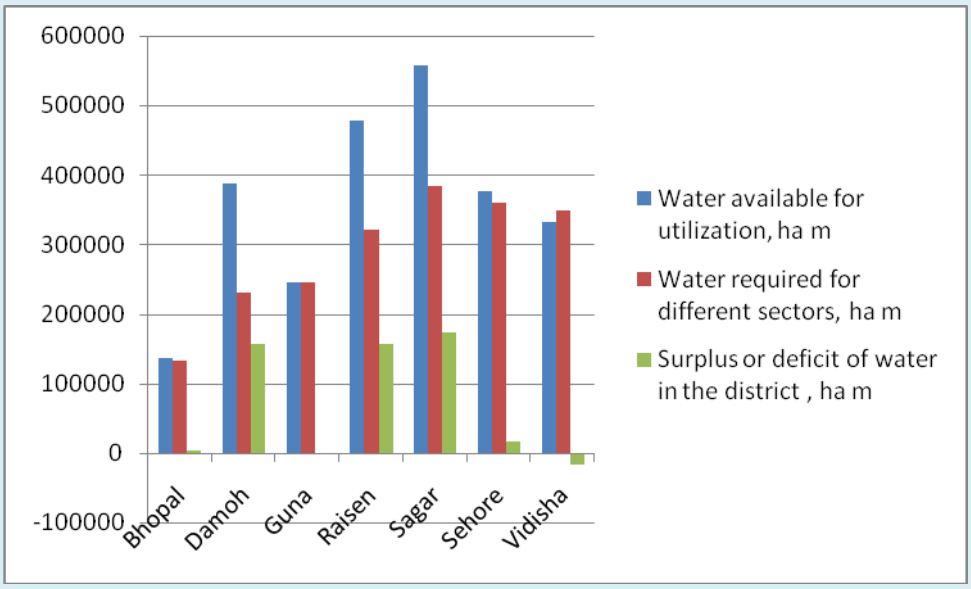


Fig. 34 Total Water needs and supply of different districts of ACZ V - Vindhya Plateau (ha-m)

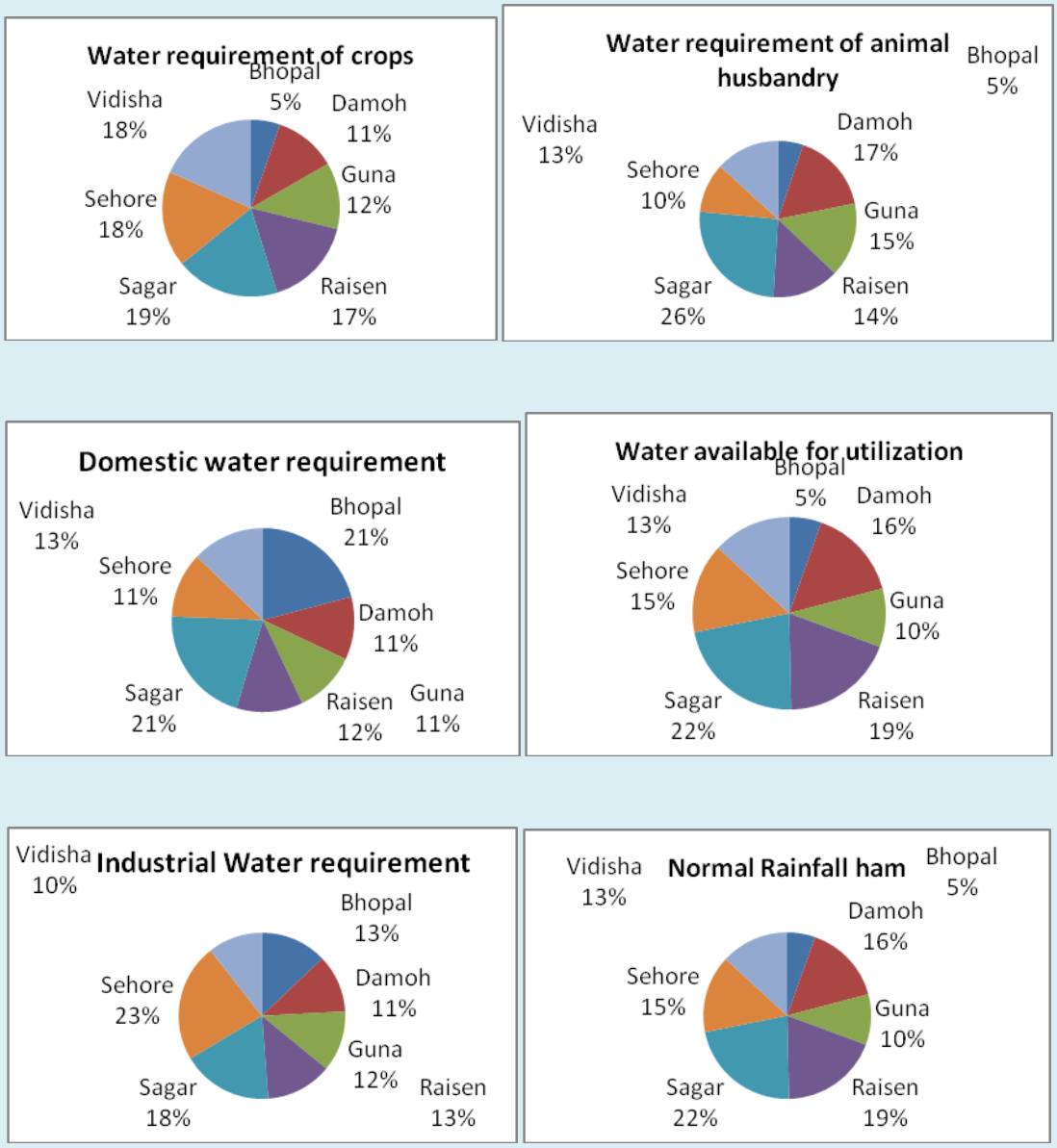


Fig. 35 Abstract of water of different districts of ACZ V - Vindhya Plateau (ha-m)

Agroclimatic Zone VI - Gird region

The Agroclimatic zone VI - Gird covers five districts namely Ashoknagar, Bhind, Gwalior, Morena and Sheopur. It comes under Wheat-jowar zone having alluvial (light) soils. The zone has total geographical area of 2537383 ha, out of which forest area is 20.4% and Sheopur is the largest (56.6%) contributors. There is negligible forest area exists in Bhind as it is only 1.7% of total zonal forest. Net area sown is 51.4% where Sheopur is the least contributor (12.9%). Out of total Net Sown area of 1305022 ha, the fallow land including current fallow is 2.7 %. District wise land utilization is presented in Table 21.

Rainfall analysis

Annual rainfall ranges from 800 to 1000 mm. On an average 92 % of this rainfall occurs during monsoon i.e. June to September, 8% in winter i.e. late December and 2% in summer. Maximum rainfall occurs in the month of August narrowly followed by July. The patterns of annual rainfall occurred in different districts of Agroclimatic zone VI for years 1970 to 2014 are presented through Figures 36A-E. Mean annual rainfall of these districts are 882.0 mm, 786.4 mm, 764.4 mm, 706.7 mm and 944 mm respectively for Ashoknagar, Bhind, Gwalior, Morena and Sheopur. The record also shows maximum ever rainfall of 1832 mm(2011) in Ashoknagar and 1810 mm (2011) in Sheopur was occurred. The annual rainfall never crosses limit of 1200 mm in Gwalior district and it only exceeds twice in Bhind and Morena districts while in two other districts it crosses ten times in 34 years. Respectively for these districts, the annual rainfall exceeded the normal annual rainfall by 55.8%, 38.3%, 64.7%, 52.9%, and 52.9% times.

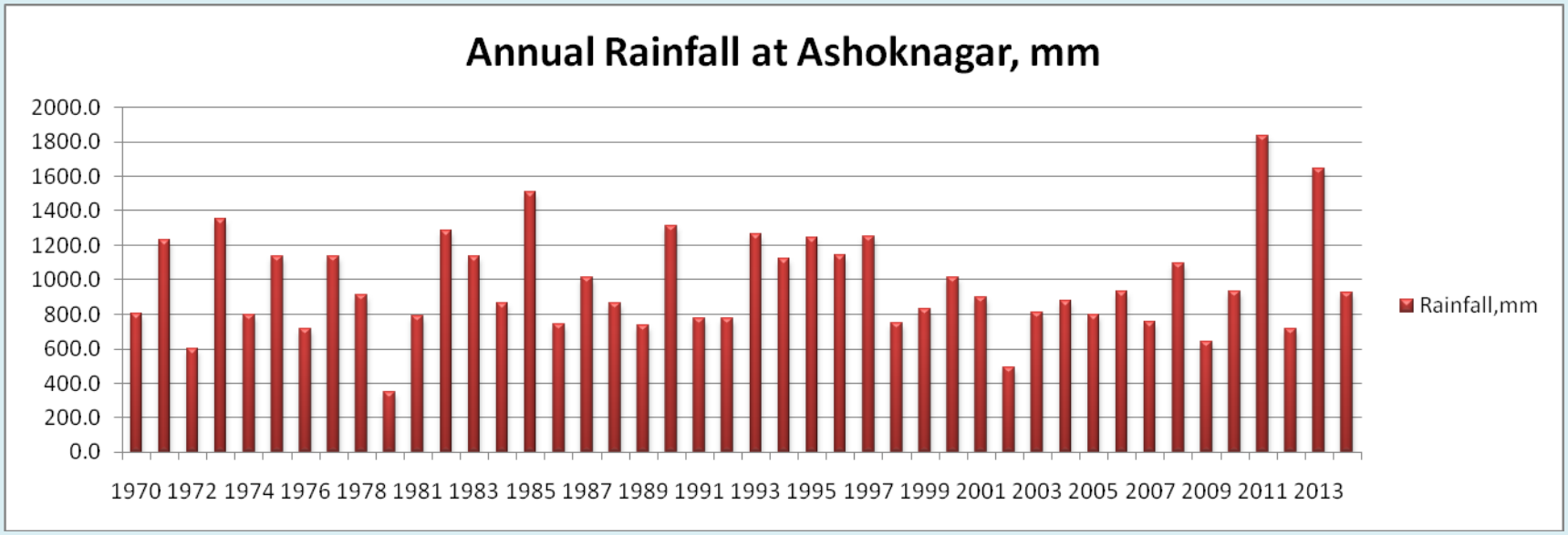
Domestic and livestock water needs

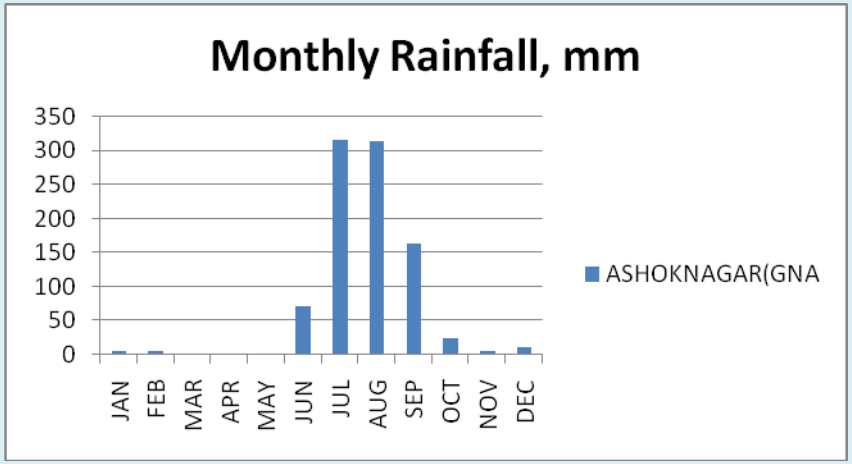
Total population of the zone is 7232173 as per Census 2011. Total human water needs of the zone is 35637 ha m where the Gwalior alone consumes 28.1% of zonal domestic water demand followed by Morena (27.2%) and Bhind (23.5%) districts. Sheopur district has minimum water needs of only 3390 ha-m. Table 22 illustrates water requirement towards human needs as well as for live stock. Live stock population comprises of cattle both cross breed and indigenous, buffalo, bovine, sheep, goat, horses and ponnies, mules, donkey, pigs, dogs, rabbits, fowls, ducks, turkey and other poultry.

Table 21 Total Area and Classification of Area In Each District of Gird Region MADHYAPRADESH State for the year ending 2013- 14															
				Not Available For Cultivation			Other Uncultivated Land Excluding Fallow Land			Fallow Land					
DISTRICT NAME	Reporting Area For Land Utilization Statics	Forests	Area Under Non Agricultural Uses	Barren and Unculturable Land	Total	Permanent Pastures and Other Grazing Lands	Land Under Misc Tree crops and Groves not Included in Net Area	Culturable Waste Land	Total	Fallow Lands Other than Current Fallows	Current Fallows	Total	Net Area Sown	Total Cropped Area	Area Sown more than once
(1)	(2)	(3)	(4)	(5)	6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
ASHOK NAGAR	467394	52839	29654	37770	67424	12422	7	20779	33208	1869	945	2814	311109	496445	185336
BHIND	445204	8806	37465	22425	59890	16604	522	11365	28491	4723	1962	6685	341332	382813	41481
GWALIOR	456449	111048	33978	48739	82717	13878	81	23953	37912	10295	3119	13414	211358	293795	82437
MORENA	501686	51424	41046	88824	129870	18706	101	21304	40010	4795	3905	8700	271682	396442	124760
SHEOPUR	666650	292883	39014	85109	124123	37118	1010	37998	75116	3082	1905	4987	169541	260547	91006
Total	**2537383**	**517000**	**181157**	**282867**	**464024**	**98728**	**610**	**115399**	**214737**	**24764**	**11836**	**36600**	**1305022**	**1830042**	**525020**

Table 22 : Live stock and Human water needs of ACZ VI						
	Ashoknagar	Bhind	Gwalior	Morena	Sheopur	Zone Total
Cross breed Cattle	11382	7530	5723	12715	560	37910
Water Req. (l/day)	1707300	1129500	858450	1907250	84000	5686500
Indigenous Cattle	230187	102030	182221	129199	244573	888210
Water Req. (l/day)	23018700	10203000	18222100	12919900	24457300	88821000
Buffalo	120889	219145	226089	623861	144961	1334945
Water Req. (l/day)	18133350	32871750	33913350	93579150	21744150	200241750
Bovine	362458	328705	414033	765775	390094	2261065
Water Req. (l/day)	54368700	49305750	62104950	114866250	58514100	339159750
Sheep	2658	5808	15211	14758	7261	45696
Water Req. (l/day)	26580	58080	152110	147580	72610	456960
Goat	86420	95660	164062	164010	123704	633856
Water Req. (l/day)	864200	956600	1640620	1640100	1237040	6338560
Horse & Ponies	114	264	107	461	55	1001
Water Req. (l/day)	3705	8580	3477.5	14982.5	1787.5	32532.5
Mules	0	49	45	232	1	327
Water Req. (l/day)	0	1592.5	1462.5	7540	32.5	10627.5
Donkey	63	332	466	2295	640	3796
Water Req. (l/day)	2047.5	10790	15145	74587.5	20800	123370
Camels	0	5	164	237	132	538
Water Req. (l/day)	0	575	18860	27255	15180	61870
Pigs	965	5146	2407	8618	3314	20450
Water Req. (l/day)	9650	51460	24070	86180	33140	204500
Dogs	9579	5313	7455	6056	2605	31008
Water Req. (l/day)	47895	26565	37275	30280	13025	155040
Rabbits	24	113	1	29	8	175
Water Req. (l/day)	15.36	72.32	0.64	18.56	5.12	112
Elephants	0	0	0	0	16	16
Water Req. (l/day)	0	0	0	0	2400	2400
Fowls	20399	9190	24018	42337	29138	125082
Water Req. (l/day)	5099.75	2297.5	6004.5	10584.25	7284.5	31270.5
Ducks	2	44	40	102	0	188
Water Req. (l/day)	0.5	11	10	25.5	0	47

Turkeys	0	0	0	0	0	0
Water Req. (l/day)	0	0	0	0	0	0
Other Poultry	0	0	32	0	8	40
Water Req. (l/day)	0	0	8	0	2	10
TWR lpd	99032383	95405957	118039967	227082368	107149927	646710603
TWR ha m	3584	3454	4270	8224	3876	23408
Human Population	844979	1703562	2030543	1965137	687952	7232173
TWR human, ha-m	4164	8394	10006	9683	3390	35637





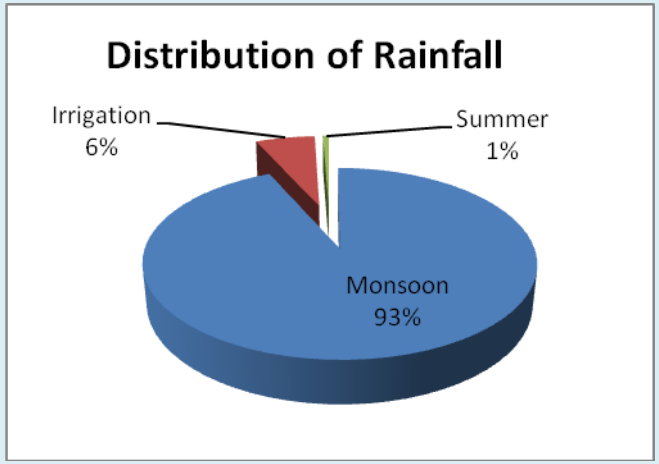
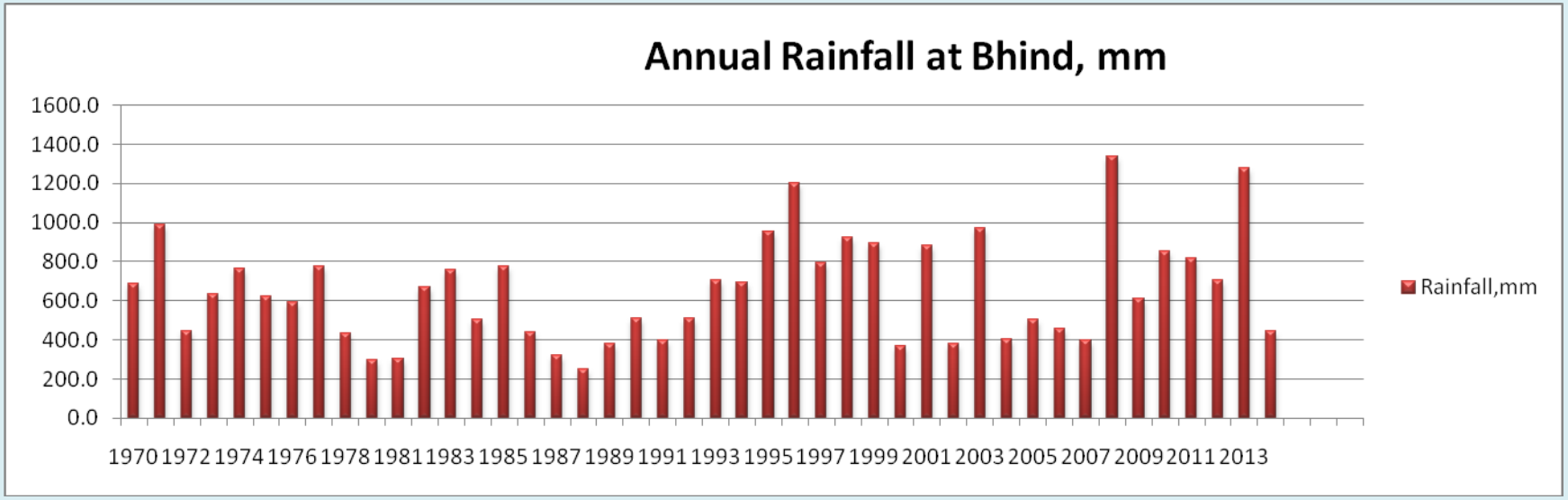
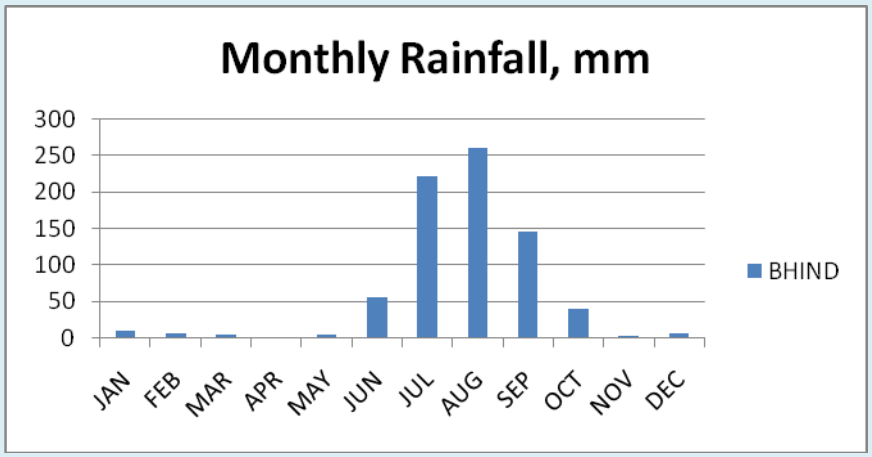


Fig. 36A Rainfall analysis at district Ashoknagar, Agro-Climatic Zone –VI, Gird Region





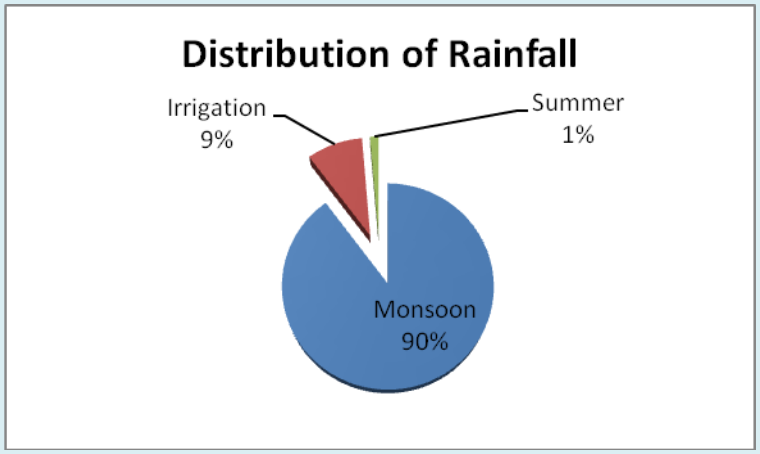
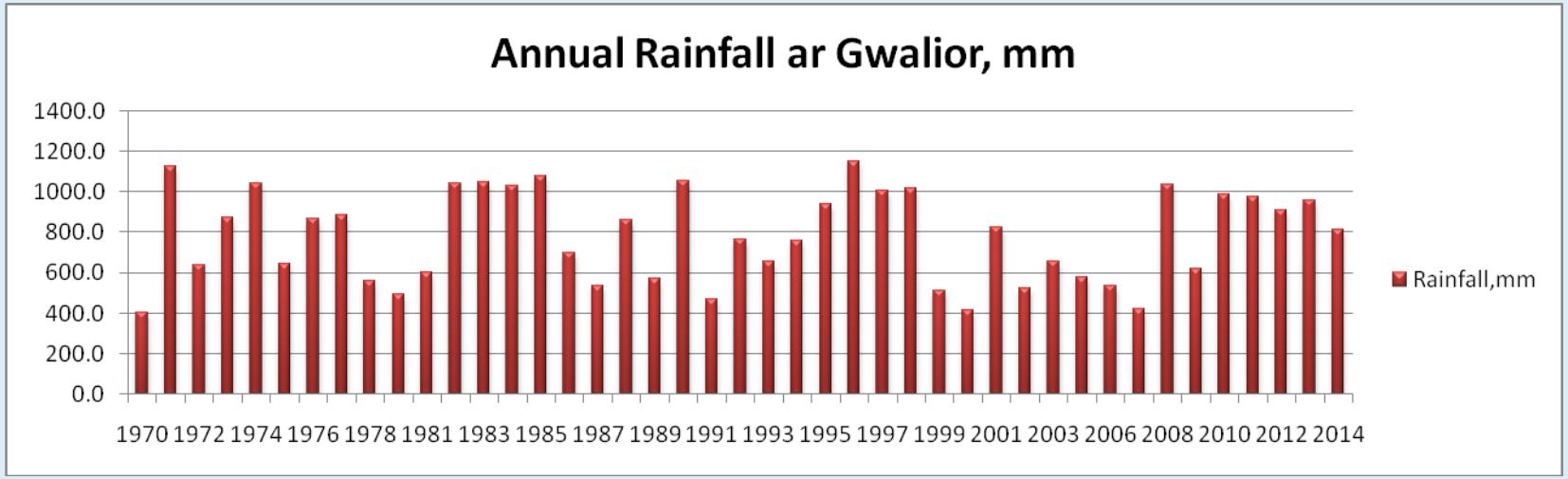
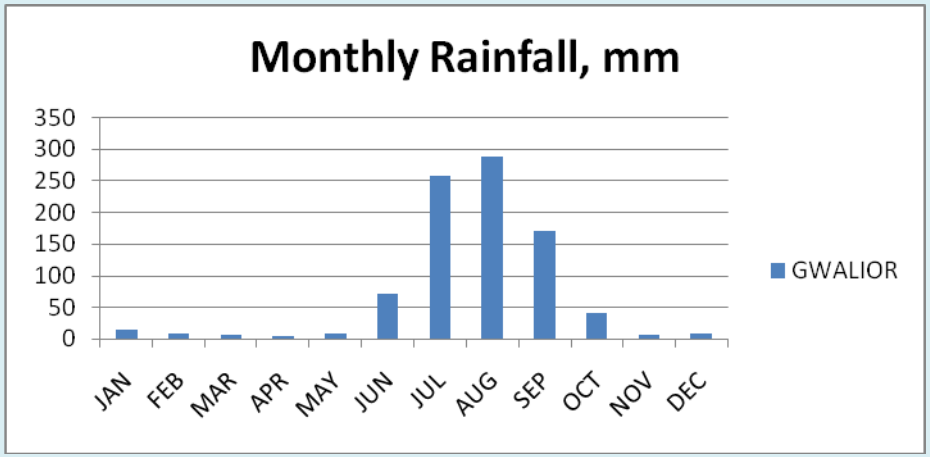


Fig. 36B Rainfall analysis at district Bhind, Agro-Climatic Zone –VI, Gird Region





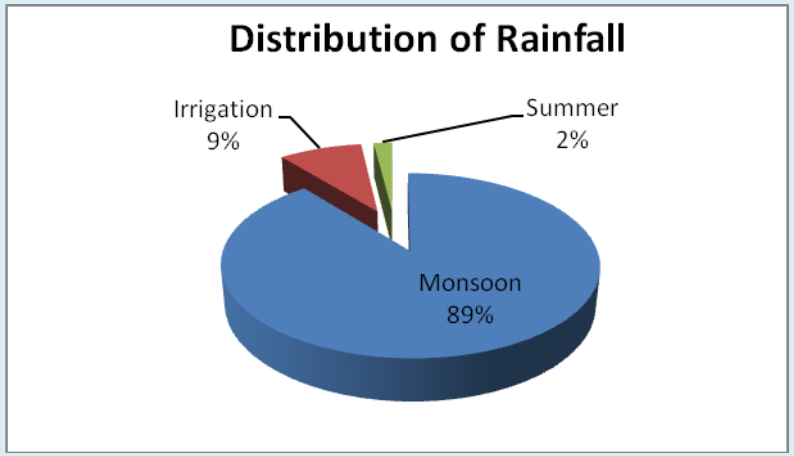
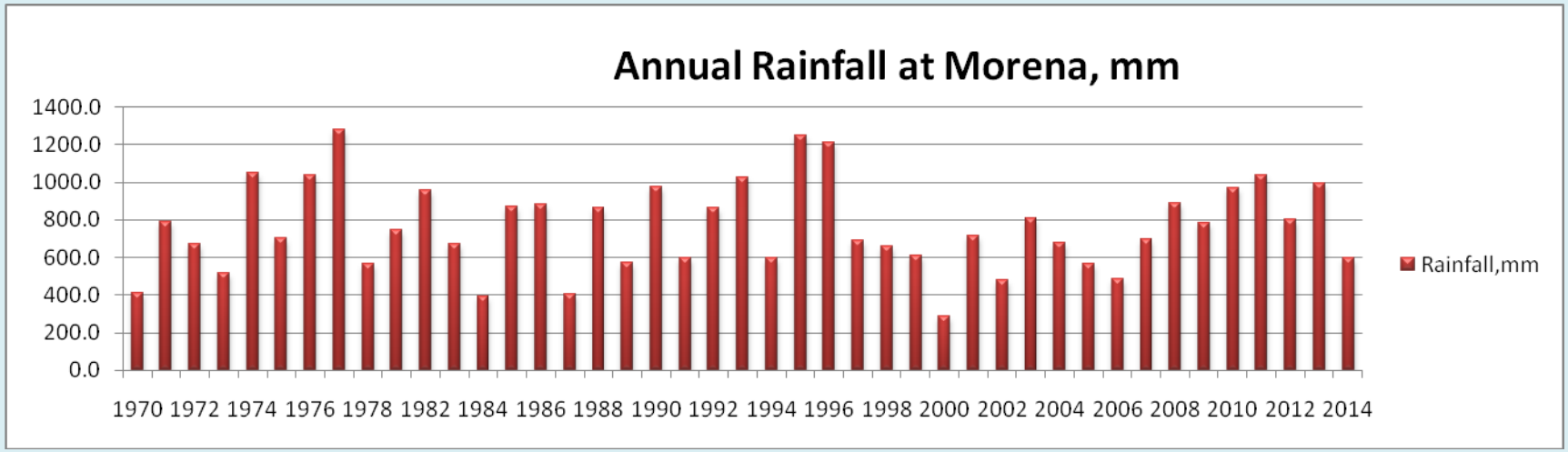
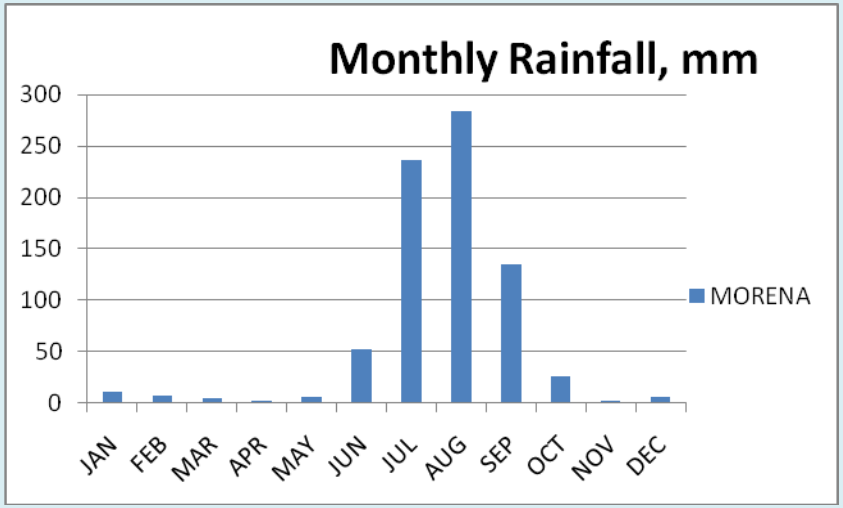


Fig. 36C Rainfall analysis at district Gwalior, Agro-Climatic Zone –VI, Gird Region





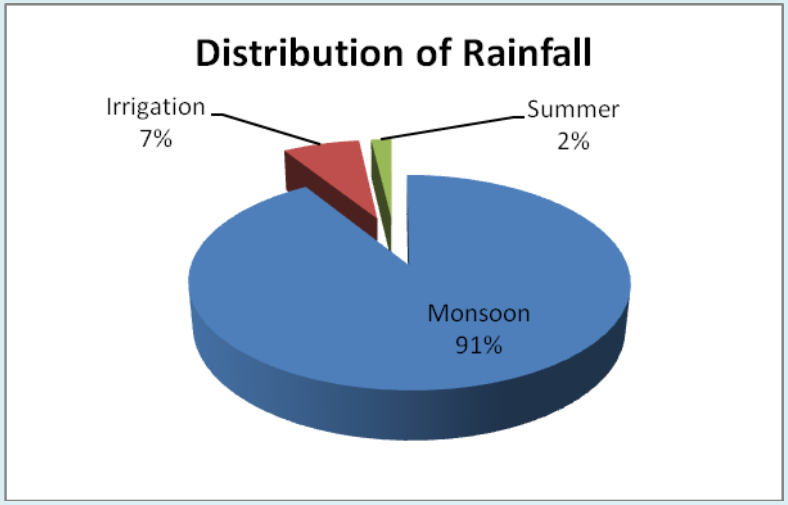
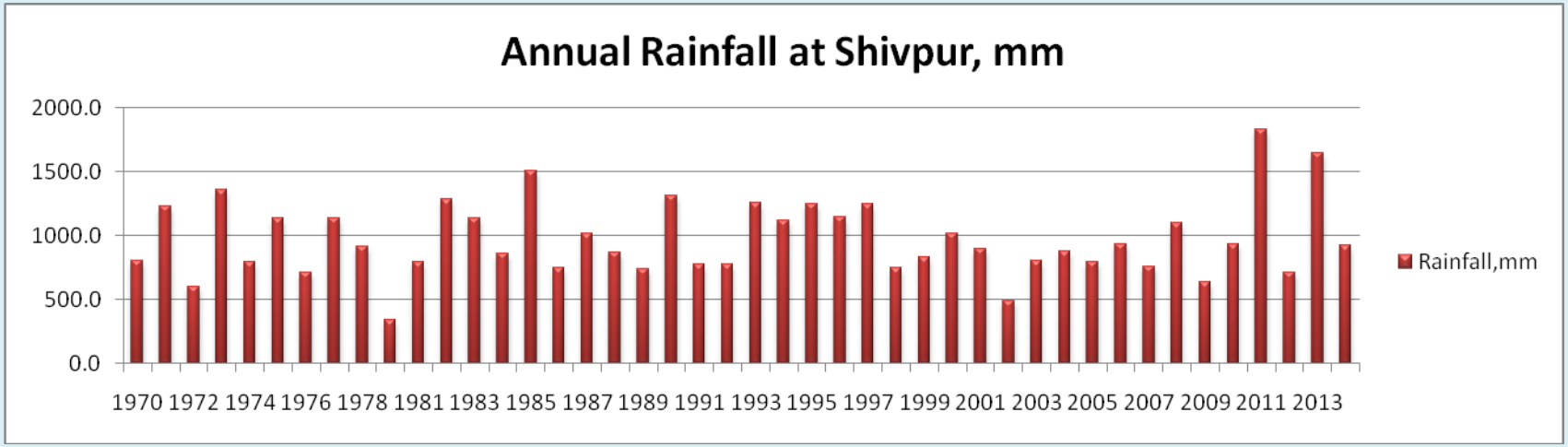
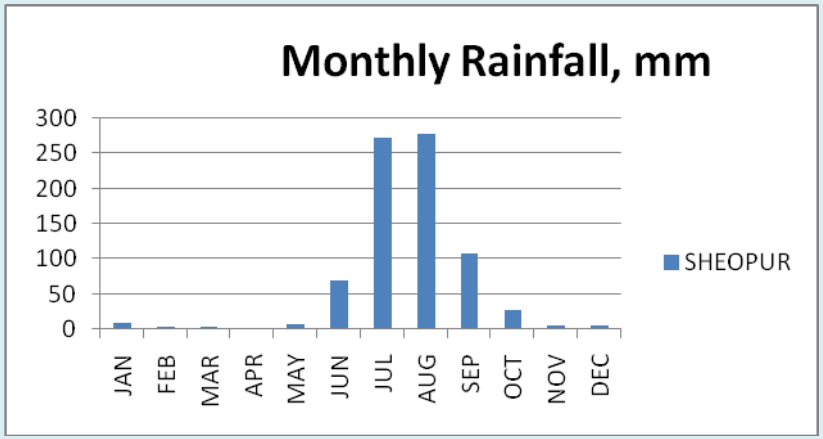


Fig. 36D Rainfall analysis at district Morena, Agro-Climatic Zone –VI, Gird Region





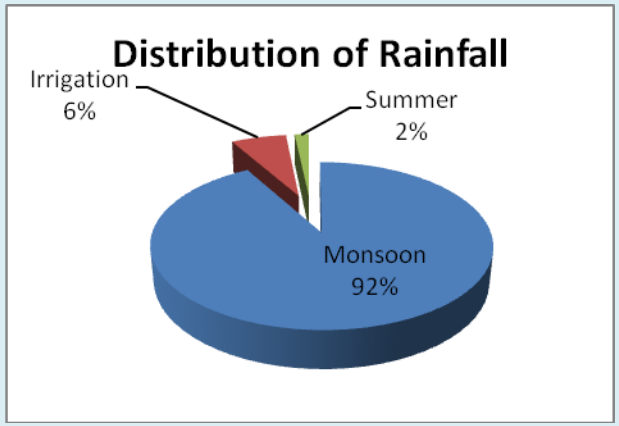


Fig. 36E Rainfall analysis at district Shivpur, Agro-Climatic Zone –VI, Gird Region

The indigenous cattles are about 23 times more than the cross breed cattles and Morena district has maximum percentage (9.8%) of cross breed cattle followed by Bhind (7.3%) and Ashoknagar (4.9%). This indicates that the zone has tremendous scope for breeding improvement programmes. Bovine is the main cattle class and out of available 2261065, Morena has maximum share of 33.8%. Similarly Morena has 46.7 % of total buffalo population of the zone. Ashoknagar has the least (9%) buffalo population and Sheopur has the least bovine population (17.1%). The sheep is mostly populated in Gwalior and Morena totaling 65.6% of the zone. These two districts also have more number of Goats having approximately 26 % of zonal population in each. Other common animal of the zone is Fowls (125082), dogs (31008) and pigs (20450). Fowls are mostly populated in Morena district (33.8%). The zone has only numeric numbers of animals like rabbits, mules, camels, horses and donkeys. Total water needs comes out 23408 ha m. Livestock water needs of Morena is maximum (35.1%) followed by Gwalior (18.2%), Sheopur (16.5%), Ashoknagar (15.3%) and Bhind (14.7%).

Water requirement of crops

The zone is a Wheat-Jowar zone has 554384 ha under wheat but only 9015 ha under jowar. Other major crops are gram (154660 ha), soyabean (223361ha), pigeon pea (87379 ha), rapeseed and mustard (27760 ha) and maize (43632 ha). Apart from this other pulses (rabi) are also taken in 33834 ha and in Kharif it occupies 46513 ha. Ashoknagar dominates in wheat, gram, other pulses (kharif and rabi) and soybean as it has area under these crops respectively as 25.1%, 72.6 %, 65.6 %, 80.7 % and 72.9 % of the zonal crop coverage. Rapeseed and mustard is the important crop of the zone and Bhind with 43.6 % area coverage and Morena with 32.5% crop coverage dominate in the zone. Table 23A-B. Based on growing period, crop coefficient values, the water requirement of all the crops were worked out and presented in Table 23A. Total yearly water requirement of the crops of the zone is 736966 ha m. The major user of water, in terms of crop water requirement, is Ashoknagar district (23.9%) followed by Morena (21.7), Bhind (19.4%), Gwalior (19.1%), and Sheopur (15.7%). Figure 37-39 depicts crop water requirement of major crops in the districts of the zone.

Table 23 A : Water requirement of field crops in Gird region , ha m										
Crops	Ashoknagar		Bhind		Gwalior		Morena		Sheopur	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Rice	1409	1124	4800	3662	57509	41579	540	446	15566	12858
Jowar (Kharif)	34	17	4858	2361	3306	1504	326	174	491	262
Jowar (Rabi)	0	0	0	0	0	0	0	0	0	0
Bajra	0	0	29763	12130	7047	2689	111048	49661	13685	6120
Maize	4551	2545	0	0	41	20	110	64	896	524
Ragi	0	0	0	0	0	0	0	0	0	0
Wheat	139588	81073	104177	56839	119285	65082	102492	59377	88842	51469
Barley	669	371	4492	2339	838	436	1590	879	319	176
Other Cereals and Millets (Kharif)	0	0	0	0	0	0	0	0	0	0
Other Cereals and Millets (Rabi)	0	0	0	0	0	0	0	0	0	0
Gram	112313	60043	13004	6531	16754	8414	4359	2324	8230	4389
Arhar (Tur)	701	440	3261	1958	805	461	12686	8281	1894	1236
Other Pulses (Rabi)	22220	11146	7801	3676	2623	1236	1114	557	76	38
Other Pulses (Kharif)	37551	18878	1761	846	4295	1956	1224	637	1682	875
Sugarcane	342	465	48	62	1543	1928	366	503	27	37
Groundnut	420	242	0	0	488	251	164	99	67	40
Castor seed	0	0	0	0	0	0	0	0	0	0
Sesamum	581	313	8500	4378	9931	4847	3666	2044	10935	6097
Rapeseed and Mustard	3156	1614	184782	88557	49682	23810	137860	70619	47985	24580
Linseed	3	2	0	0	42	21	2	1	14	7
Soyabean	162861	69656	124	51	5596	2135	450	201	54330	24296
Niger seed	0	0	0	0	0	0	0	0	0	0
Sunflower	0	0	0	0	0	0	0	0	0	0
Safflower	0	0	0	0	0	0	0	0	0	0
Other Oilseeds	0	0	3903	2233	697	378	468	290	0	0
Cotton	0	0	0	0	0	0	0	0	248	209
Jute	0	0	0	0	0	0	1054	890	0	0
Mesta	0	0	0	0	0	0	0	0	0	0
Sanhemp	0	0	103	86	5	4	0	0	0	0
Other Fibres	0	0	0	0	0	0	0	0	0	0

Table 23 B : Water requirement of fruits and vegetables crops in Gird region, ha m

Crops	Ashoknagar		Bhind		Gwalior		Morena		Sheopur	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Chillies	518	566	12	12	33	34	260	281	0	0
Ginger	6	8	0	0	0	0	12	15	0	0
Turmeric	0	0	0	0	0	0	0	0	0	0
Betel nut	0	0	0	0		0	0	0	0	0
Garlic	47	77	3	5	4	6	18	30	272	450
Coriander	808	1172	0	0	31	41	0	0	3123	4616
Other Condiments and Spices	0	0	0	0	2	2	0	0	1	1
Mango	87	143	0	0	1	2	0	0	0	0
Banana	0	0	0	0	0	0	0	0	0	0
Citrus Fruits	0	0	0	0	7	9	6	8	0	0
Grapes	2	2	0	0	0	0	0	0	0	0
Papaya	5	8	0	0	1	2	0	0	0	0
Other Fruits	29	48	1	2	56	85	60	99	15	25
Potato	350	323	803	702	902	788	2076	1925	17	16
Sweet Potato	1	1	2	1	117	76	11	8	0	0
Onion	137	238	29	48	64	103	111	195	37	65
Other Vegetables (Kharif)	139	100	405	278	1062	691	745	554	332	247
Other Vegetables (Rabi)	1068	761	871	583	1003	672	1044	742	299	213
Opium	0	0	0	0	0	0	0	0	0	0
Tobacco	0	0	0	0	0	0	0	0	0	0
Other Plantation Crops	0	0	23	40	46	78	0	0	0	0
Fodder Crops	6849	5010	9286	6495	6401	4242	12580	9525	9914	7507
Other Non Food Crops	0	0	1	1	3578	4286	0	0	0	0

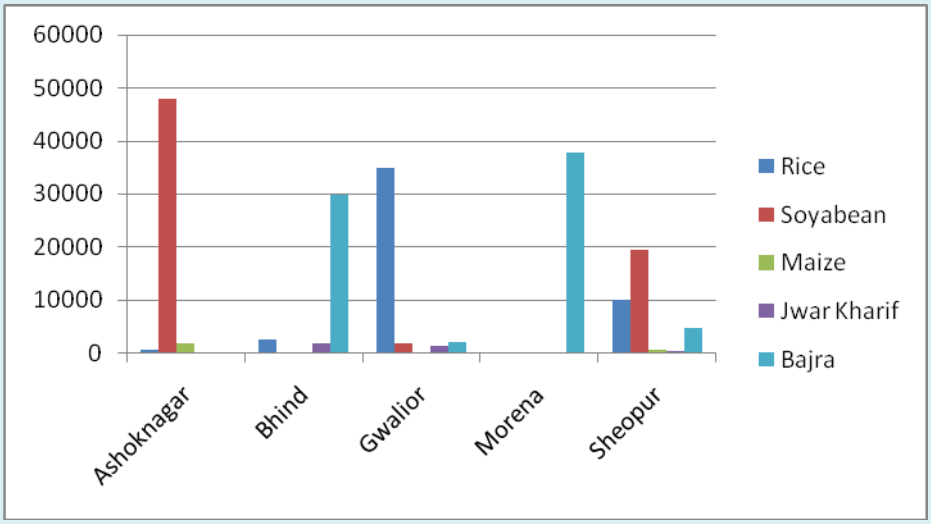


Fig. 37 Crop water requirement of major kharif crops of ACZ VI - Gird region in ha m

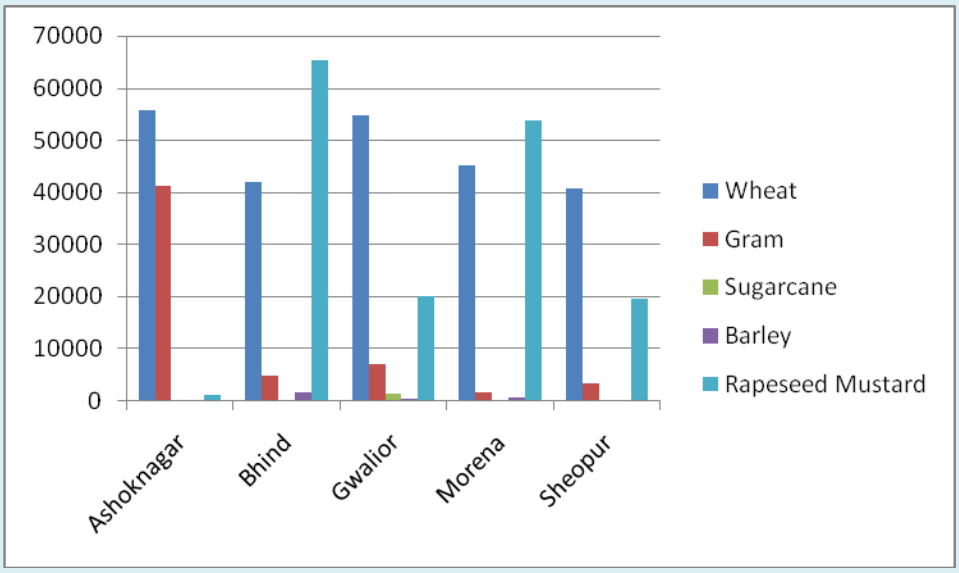


Fig.38 Crop water requirement of major rabi crops of ACZ VI - Gird region in ha m

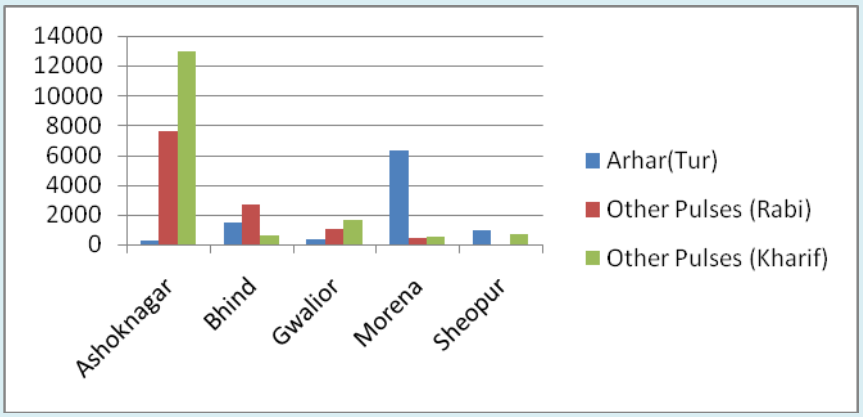


Fig. 39 Crop water requirement of pulse crops of ACZ VI - Gird region in ha m

Only coriander 3962 ha, potato (4148 ha) are mostly taken in this zone (Table23B). Sheopur dominates in coriander cultivation with 79.8% share, while Morena dominates in Potato cultivation with 50.0% share. Gwalior has maximum acreage (39.6%) in other vegetable (Kharif) and Ashoknagar with Gwalior and Morena contributes 72.7% of Rabi other vegetables.

Water budget

The agroclimatic zone VI (ACZ VI)- Gird region receives total quantum of water towards rainfall as 2095116 ha m. Maximum (30.0%) of it receives in district Sheopur followed by Ashoknagar (19.7 %). Rest of the three districts receives approximately the same about of about 17%. National Commission on Agriculture has laid down norms for water budgeting of an area and as per its estimate the losses of water as evaporation, surface water flow and ground water flow out of the area is calculated in present estimation. Similarly, addition of water into the area as runoff generated from the zone, addition of soil moisture and to the ground water is also computed. The water budget so generated for ACZ VI is presented in Table 24. The immediate evaporation losses that occurs during the rainfall is taken as 17.5% of total rainfall and it is 366645 ha m for the zone. 28.7% rainfall converts into surface flow and it is 601298 ha-m. It is considered that 10.549 % (99894 ha-m) of surface flow goes out of the zone. Ground water also adds to the surface flow and it is taken as 23.739% of surface flow. Thus, surface flow arrives to be 946951 ha-m which is 45.198% of total precipitation.

Evaporation takes place from open water body, soil surface, forest and vegetation and also from rise of water table, and, respectively it is taken as 7.916% (74961 ha-m) of total surface flow, 31.504% (293687 ha-m) of total soil moisture storage, 30.826% (287367 ha-m) of total soil moisture and 18.5451% (83082 ha-m) of total ground water. Part of rainfall as recharge enriches ground water and it is 12.5 % (261890 ha-m). There is an addition to the ground water from streams and flood flows which is - 4.851 % (-45937 ha-m) of total surface flow. The total utilizable surface and ground water for the ACZ VI computed as 602989 ha-m.

The soil moisture increases due to rainfall as well as from irrigation. 41.3% of rainfall and 7.067% of total surface flow is considered as soil moisture storage. Total zonal soil moisture storage is 932222 ha-m and out of this 351196 ha-m is available as ET for the crops.

Table 24 : Water budgeting of Gird region, ha-m

S.N	Particulars	A Nagar	Bhind	Gwalior	Morena	Sheopur	Zone Total
1	Normal rainfall, ha-m	412241	350108	348909	354541	629317	2095116
2	Immediate evaporation (17.5%)	72142	61269	61059	62045	110130	366645
3	Surface flow (28.7%)	118313	100481	100137	101753	180614	601298
4	From outside state(10.549% of total surface flow)	19655	16693	16636	16904	30005	99894
5	To GW from flood flows (-4.851% of total surface flow)	-9039	-7676	-7650	-7774	-13798	-45937
6	From GW to surface flow(23.739% of total surface flow)	44232	37565	37436	38041	67523	224797
7	From irrigated area to surface flow(7.067% of total surface flow)	13168	11183	11145	11325	20101	66921
8	Total surface flow(45.198% of total ppt)	186325	158242	157700	160245	284439	946951
9	Evaporation losses from reservoirs and tanks (7.916% of total surface flow)	14749	12526	12484	12685	22516	74961
10	Flow into seas and outside state (43.445% of total surface flow)	80949	68748	68513	69619	123574	411403
11	Utilizable surface flow (48.639% of total surface flow)	90626	76967	76704	77942	138348	460587
12	Water available for ground water storage (12.5%)	51530	43764	43614	44318	78665	261890
13	From streams and flood flows to GW(4.851% of total surface flow)	9039	7676	7650	7774	13798	45937
14	From irrigation to GW addition (S.N.15-(12+13))	28030	23805	23724	24107	42790	142456
15	Total GW (21.492% of total ppt)	88599	75245	74988	76198	135253	450282
16	Evaporation and rise of water table (18.451% of total GW)	16347	13883	13836	14059	24955	83082
17	Regeneration into streams(49.924% of total GW)	44232	37565	37437	38041	67524	224799
18	GW available utilization(31.625% of total GW)	28019	23796	23715	24098	42774	142402

19	Total utilizable surface + GW (S.N. 11+18)	118646	100764	100418	102039	181122	602989
20	Soil moisture storage (41.3% of normal rainfall)	170256	144595	144099	146425	259908	865283
21	From irrigated area to soil moisture(7.067% of total surface flow)	13168	11183	11145	11325	20101	66921
22	Total soil moisture storage (44.495% of total ppt)	183427	155781	155247	157753	280015	932222
23	Evaporation losses from soil moisture (31.504% of total soil moisture storage)	57787	49077	48909	49699	88216	293687
24	Evap. losses from forest and other veg. (30.826% of total soil moisture)	56543	48021	47856	48629	86317	287367
25	Soil moisture available for ET from crops (37.673 % of total soil moisture)	69102	58687	58486	59430	105490	351196
26	Water requirement of crops	175957	143293	141223	160224	116267	736964
27	Water requirement of animal husbandry	3584	3454	4270	8224	3876	23408
28	Domestic water requirement	4164	8394	10005	9683	3390	35636
29	Industrial Water requirement @ 6 % of available fresh water	23993	15779	19027	14937	20246	93982
30	Water available for utilization (S.N. 19+25)	187748	159451	158905	161470	286612	954185
31	Water required for different sectors (26+27+28+29)	207698	170920	174525	193068	143779	889990
32	Surplus or deficit of water in the district (30-31)	-19950	-11469	-15620	-31598	142833	64195

Each and every district of the ACZ VI zone contributes in same proportion in zonal water budgeting as the quantum of rainfall of each district contributes in zonal rainfall quantum owing to rainfall based water distribution.

Utilization of water takes place in four major categories. These are, domestic and animal water needs, crop water requirement and requirement of water for industrial and recreation. A water need of different sectors in districts of ACZ VI is presented in Fig. 40. Total crop water requirement of the zone is 736964 ha m and out of which

Ashoknagar and Morena together needs water towards crops as 45.6% of zonal total. The least crop water demand comes from Sheopur district (15.7 %). In comparison to the crop water demand the water demand towards domestic and animal husbandry is very low as it is respectively 35636 ha m and 23408 ha m. Owing to higher population in Gwalior and Morena the domestic demand is about 55.2% of the zonal demand. Sheopur registers the least domestic water demand i.e. only 16.5% of zonal total. Morena district has more animal husbandry and demand for 35.1% of the zonal water needs of it. The industrial demand is computed as 6% of available water thus total zonal demand comes out as 93982 ha m.

Total water needs and supply of different districts of ACZ VI is presented in Fig. 41, the excess of water is also shown in the figure. The water available for utilization at zonal level is 954185 ha-m. The maximum share (30.0%) is available at Sheopur district followed by Ashoknagar, Morena and Bhind. The total zonal water demand is 944785 ha-m and Ashoknagar district requires the maximum share of 22.5 % followed by Morena (21.9 %) and Gwalior (19.2%). The Sheopur district requires the least amount of water i.e. 17.2 % of the zonal total. As for as the excess water concerned the zone has only 9400 ha-m of surplus water. Except Sheopur all other districts are having deficit water and Morena is the most deficient state in this manner. While Sheopur is 76 % excess water but rests of the districts are 12 to 22% deficient. An abstract in pictorial form is provided in Fig 42.

Taking net sown area of these district, as per Directorate of Extension and Farmers Welfare, 311109 ha, 341332 ha, 211358 ha, 271682 ha and 169541 ha, the per hectare water excess/deficit due to this surplus water comes out to be -12 cm, -12 cm, -13 cm, -22 cm, and 76 cm. It means, the future plans to enhance crop production or alternate cropping may be based on this much depth of water.

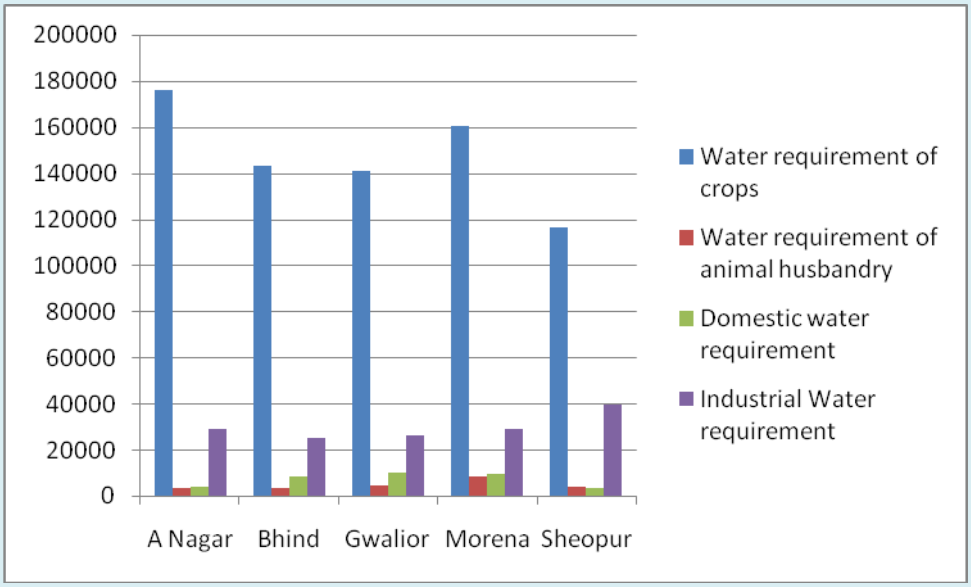


Fig. 40 Water needs of different sectors in districts of ACZ VI - Gird Region (ha-m)

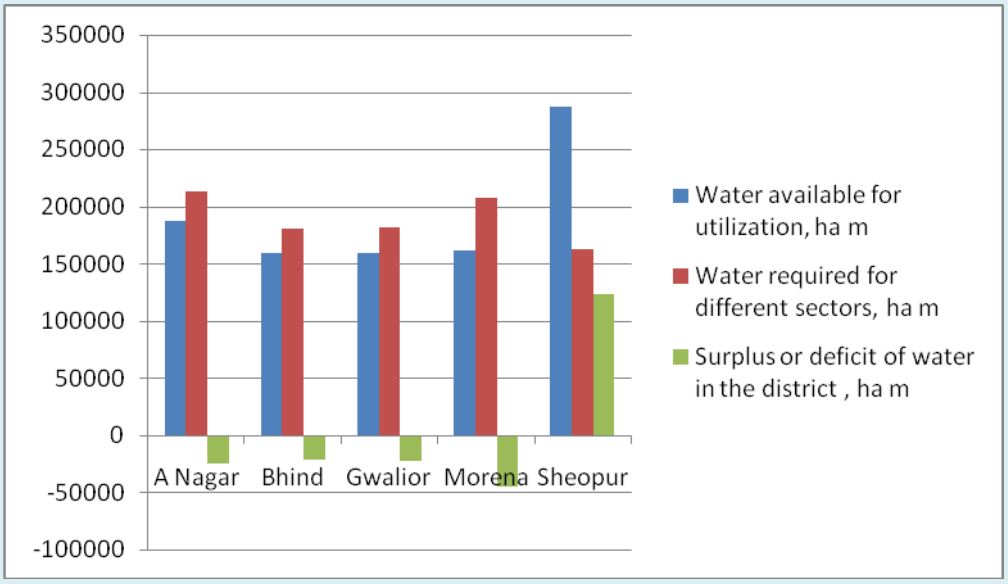
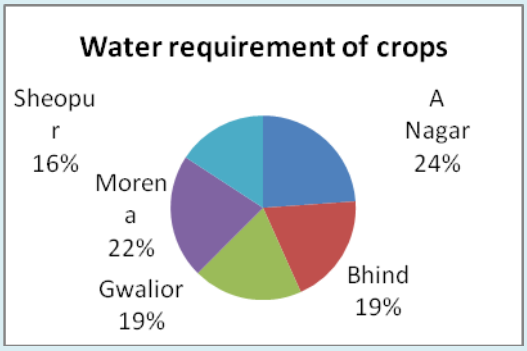
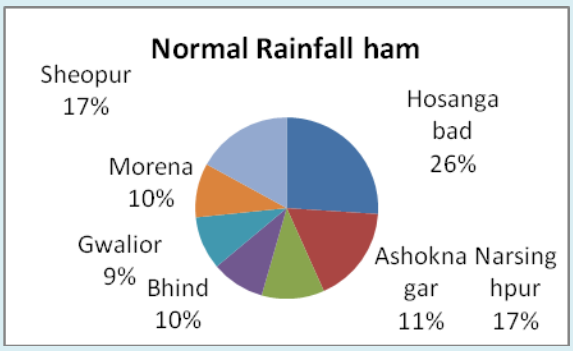
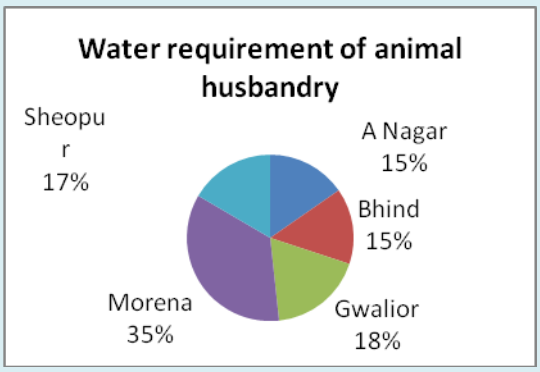
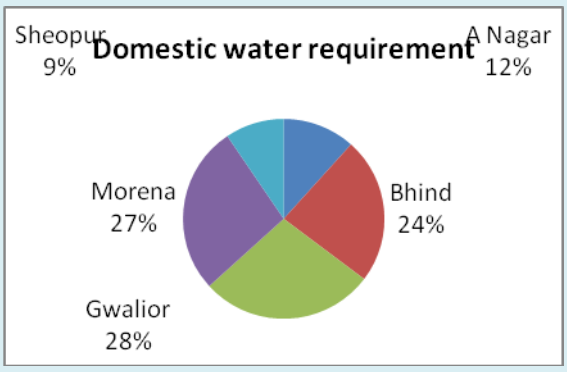


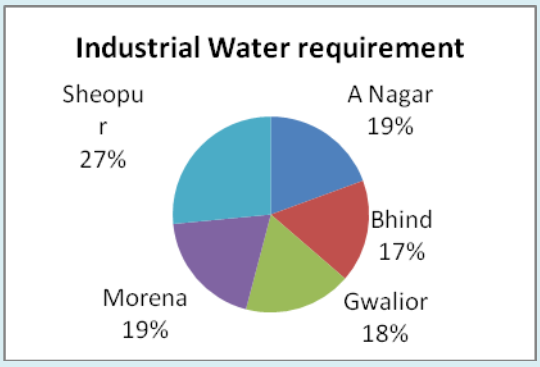
Fig. 41 Total Water needs and supply of different districts of ACZ VI - Gird Region (ha-m)











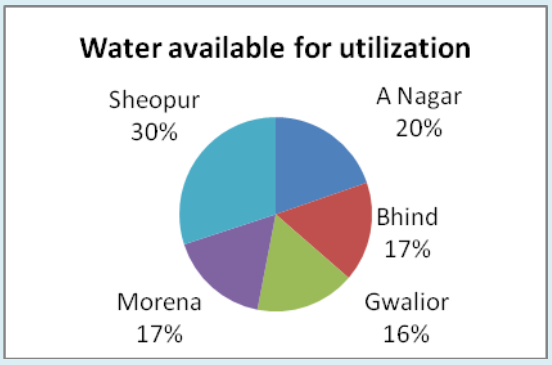


Fig. 42 Abstract of water of different districts of ACZ VI - Gird Region (ha-m)

Agroclimatic Zone VII - Bundelkhand

The Agroclimatic zone VII - Bundelkhand covers four districts namely Chhatarpur, Datia, Shivpuri and Tikamgarh. It comes under Wheat – Jowar zone having mixed red and black (medium) soils. The zone has total geographical area of 2658304 ha, out of which forest area is 24.1 % and Shivpuri is the main contributor as it occupies 51.4 % of total forest area of the ACZ VII. Datia having the least forest area of less than 5% of total zonal forest. Net area sown is 53.2 % of GA where Datia is the least contributor (14.9 %). Out of total cropped area of 2110835 ha, the fallow land including current fallow is 3.9%. District wise land utilization is presented in Table 25.

Rainfall analysis

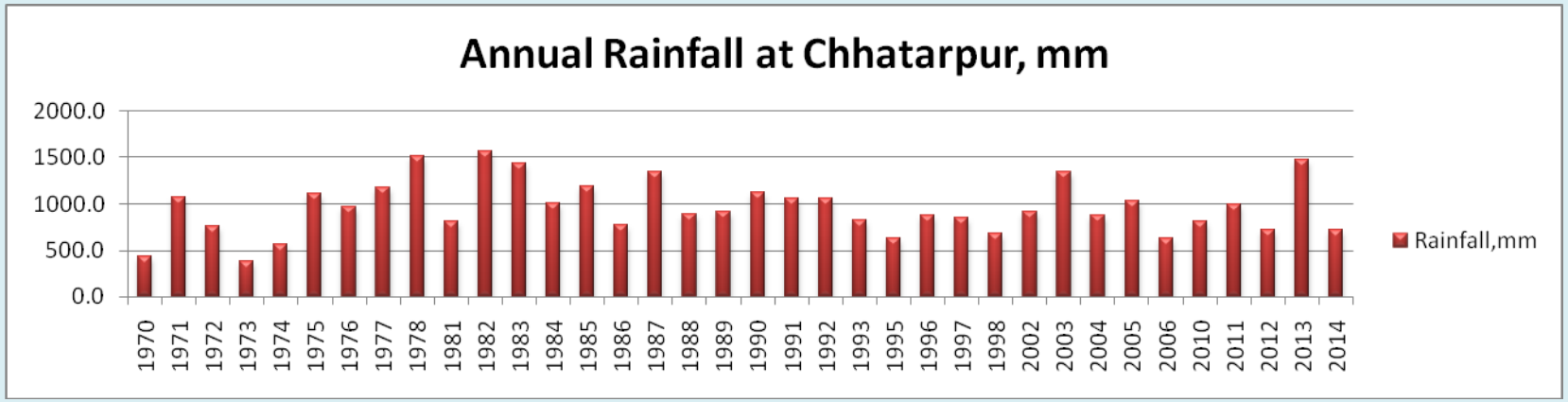
Annual normal rainfall ranges from 800 to 1400 mm. On an average 91 % of this rainfall occurs during monsoon i.e. June to September, 8% in winter i.e. late December and 1 % in summer. Maximum rainfall occurs in the month of August. The patterns of annual rainfall occurred in different districts of Agroclimatic zone VI for years 1970 to 2014 are presented through Figures 43A-D. Annual normal rainfall of these districts are 1095.1 mm, 876.3 mm, 816.3 mm and 1070.3 mm respectively for Chhatarpur, Datia, Shivpuri and Tikamgarh districts. The record also shows maximum ever rainfall of the zone occurred in Shivpuri district in 2011 (1808mm). The annual rainfall touches or crosses 1500 mm per annum only thrice in all districts except Datia where it never crosses even 1300 mm. Respectively for these districts, the annual rainfall exceeded the normal annual rainfall by 23.5%, 29.4%, 64.7%, and 44.1% times.

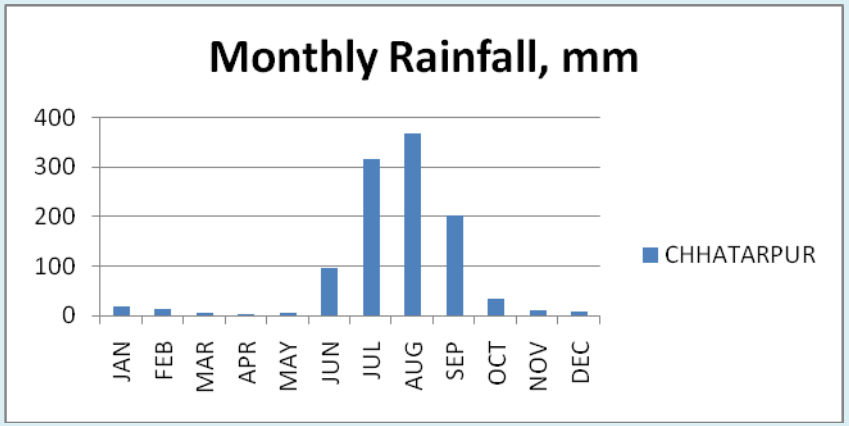
Domestic and livestock water needs

Total population of the zone is 5719970 as per Census 2011. Total human water needs of the zone is 28185 ha-m where the maximum consumption is of Chhatarpur district (8686 ha-m) followed by Shivpuri (8504 ha-m) and Tikamgarh (7120 ha-m) districts. Datia district has minimum domestic water needs of only 3875 ha-m. Table 26 illustrates water requirement towards human needs as well as for live stock. Live stock population comprises of cattle both cross breed and indigenous, buffalo, bovine, sheep, goat, horses and ponies, mules, donkey, pigs,

Table 25 Total Area and Classification of Area In Each District of Bundelkhand MADHYAPRADESH State for the year ending 2013- 14															
DISTRICT NAME	Reporting Area For Land Utilization Statics			Not Available For Cultivation			Other Uncultivated Land Excluding Fallow Land			Fallow Land		Total	Net Area Sown	Total Cropped Area	Area Sown more than once
		Forests	Area Under Non Agricultural Uses	Barren and Unculturable Land	Total	Permanent Pastures and Other Grazing Lands	Land Under Misc Tree crops and Groves not Included in Net Area	Culturable Waste Land	Total	Fallow Lands Other than Current Fallows	Current Fallows				
(1)	(2)	(3)	(4)	(5)	6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
CHHATARPUR	863036	212969	46169	1514	47683	70721	192	30065	100978	18126	16654	34780	466626	661123	194497
DATIA	307173	29416	18131	16158	34289	6010	3987	12873	22870	4828	4207	9035	211563	268507	56944
SHIVPURI	984093	330557	61627	37054	98681	25066	3821	51434	80321	12513	3994	16507	458027	713794	255767
TIKAMGARH	504002	69213	37586	54753	92339	18918	156	22453	41527	20163	2381	22544	278379	467411	189032
Total	**2658304**	**642155**	**163513**	**109479**	**272992**	**120715**	**8156**	**116825**	**245696**	**55630**	**27236**	**82866**	**1414595**	**2110835**	**696240**

Table 26 : Live stock and Human water needs of ACZ VII					
	Chhatarpur	Datia	Shivpuri	Tikamgarh	Zone Total
Cross breed Cattle	3095	630	16691	6407	26823
Water Req. (l/day)	464250	94500	2503650	961050	4023450
Indigenous Cattle	340818	106555	527805	360563	1335741
Water Req. (l/day)	34081800	10655500	52780500	36056300	133574100
Buffalo	239206	150324	370247	232231	992008
Water Req. (l/day)	35880900	22548600	55537050	34834650	148801200
Bovine	583119	257509	914743	599201	2354572
Water Req. (l/day)	87467850	38626350	137211450	89880150	353185800
Sheep	4553	3858	47405	38850	94666
Water Req. (l/day)	45530	38580	474050	388500	946660
Goat	254774	99841	304748	223571	882934
Water Req. (l/day)	2547740	998410	3047480	2235710	8829340
Horse & Ponies	257	127	178	385	947
Water Req. (l/day)	8352.5	4127.5	5785	12512.5	30777.5
Mules	358	109	7	13	487
Water Req. (l/day)	11635	3542.5	227.5	422.5	15827.5
Donkey	138	357	412	180	1087
Water Req. (l/day)	4485	11602.5	13390	5850	35327.5
Camels	0	0	3	0	3
Water Req. (l/day)	0	0	345	0	345
Pigs	6761	2082	9080	5995	23918
Water Req. (l/day)	67610	20820	90800	59950	239180
Dogs	8580	6344	18076	11386	44386
Water Req. (l/day)	42900	31720	90380	56930	221930
Rabbits	6	24	38	123	191
Water Req. (l/day)	3.84	15.36	24.32	78.72	122.24
Elephants	0	0	0	5	5
Water Req. (l/day)	0	0	0	750	750
Fowls	80731	14971	64392	81690	241784
Water Req. (l/day)	20182.75	3742.75	16098	20422.5	60446
Ducks	45	75	38	130	288
Water Req. (l/day)	11.25	18.75	9.5	32.5	72
Turkeys	7	0	0	0	7
Water Req. (l/day)	1.75	0	0	0	1.75
Other Poultry	11	0	15	0	26
Water Req. (l/day)	2.75	0	3.75	0	6.5
TWR lpd	162165714	73680335	254045121	166074039	655965209
TWR ha m	5863	2666	9190	6004	23723
Human Population	1762857	786375	1725818	1444920	5719970
TWR human, ha-m	8686	3875	8504	7120	28185





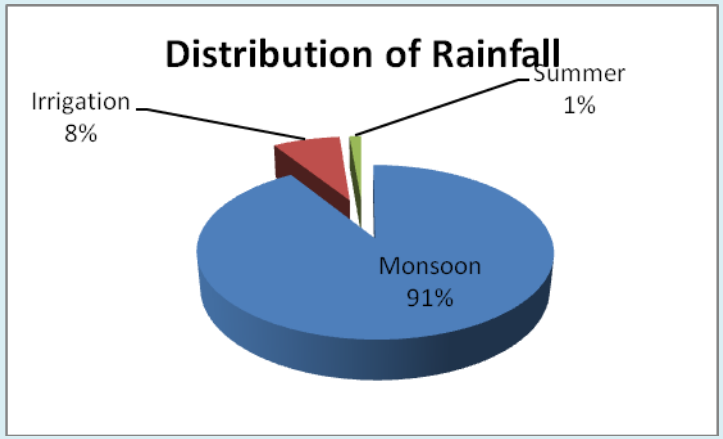
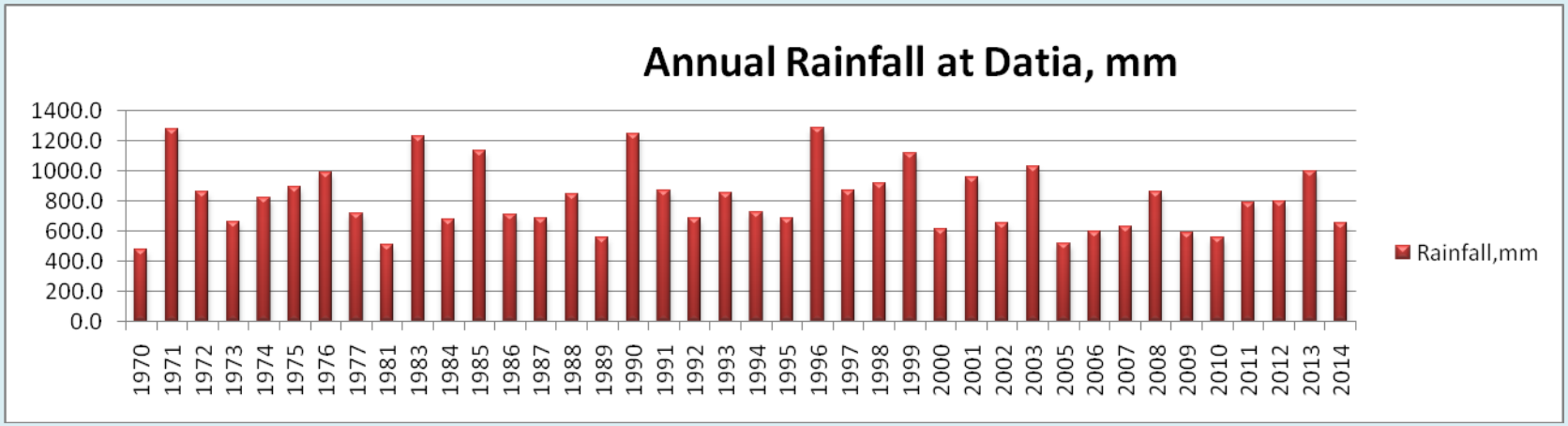
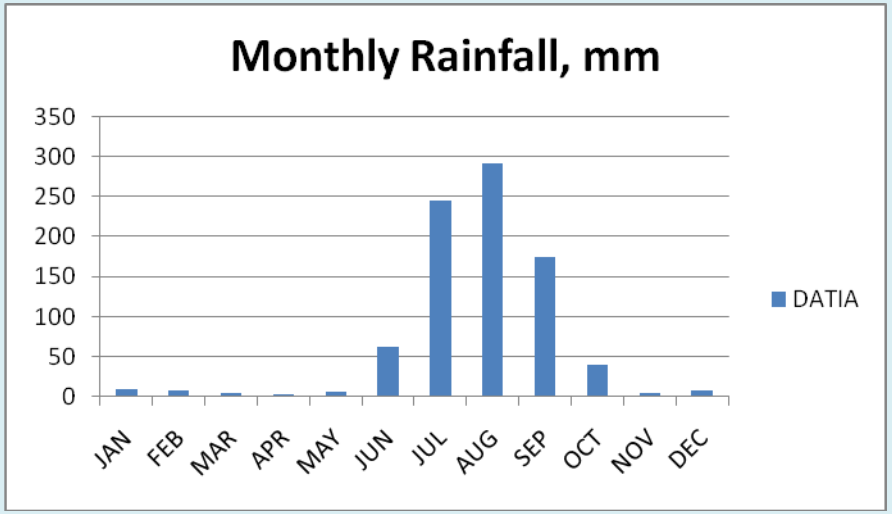


Fig. 43A Rainfall analysis at district Chhatarpur, Agro-Climatic Zone –VII, Bundelkhand





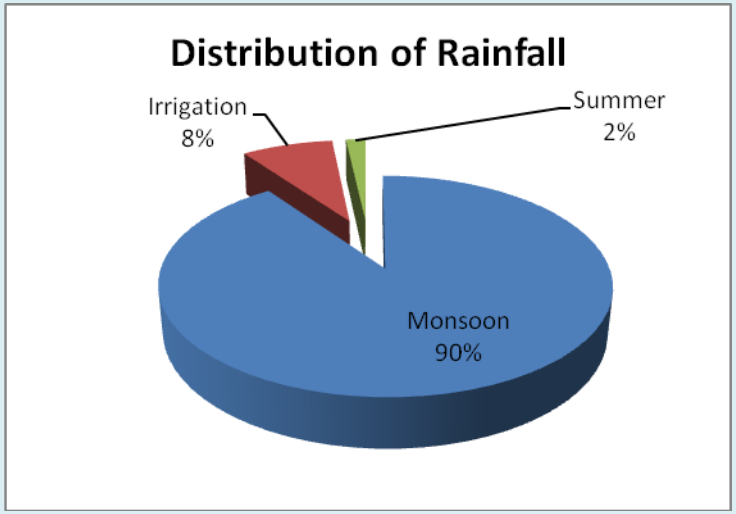
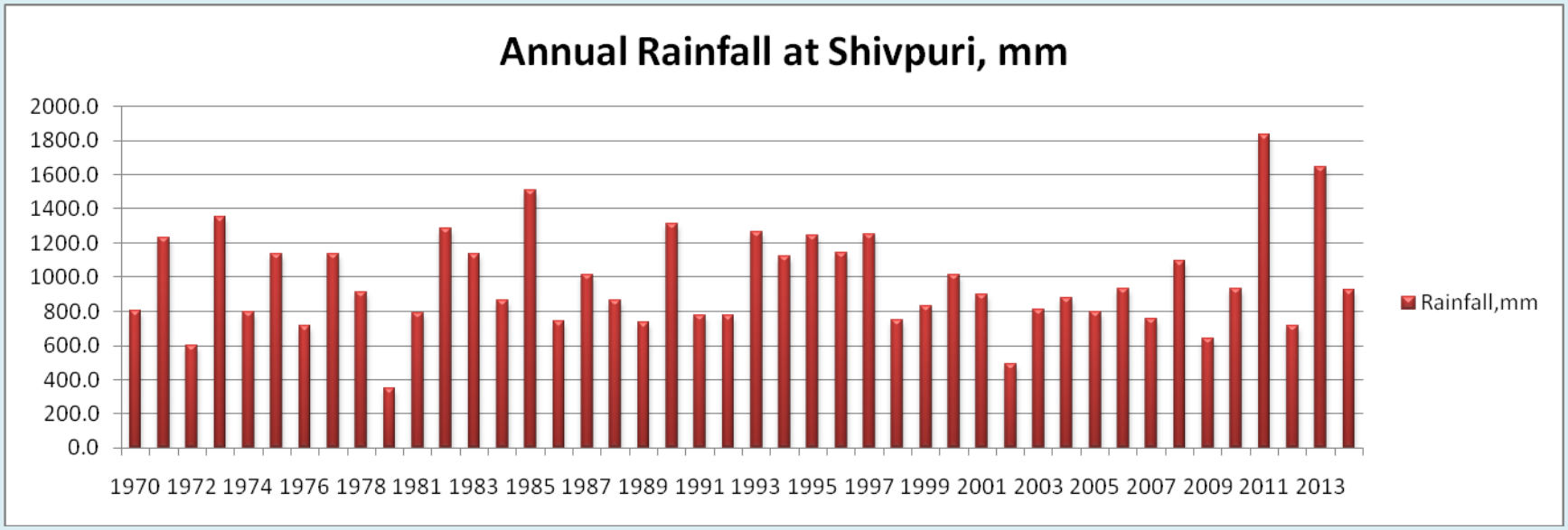
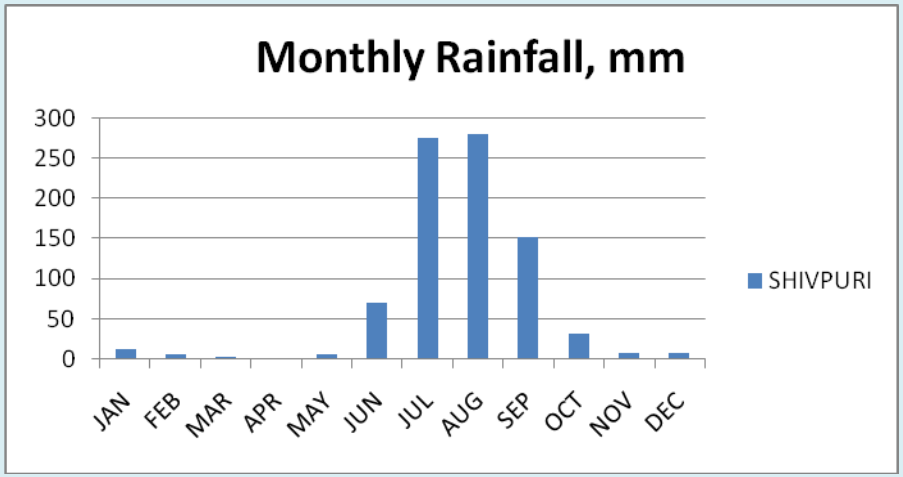


Fig. 43B Rainfall analysis at district Datia, Agro-Climatic Zone –VII, Bundelkhand





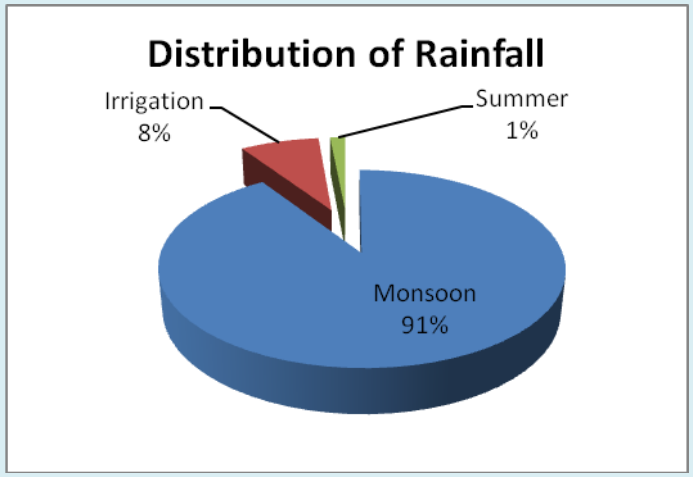
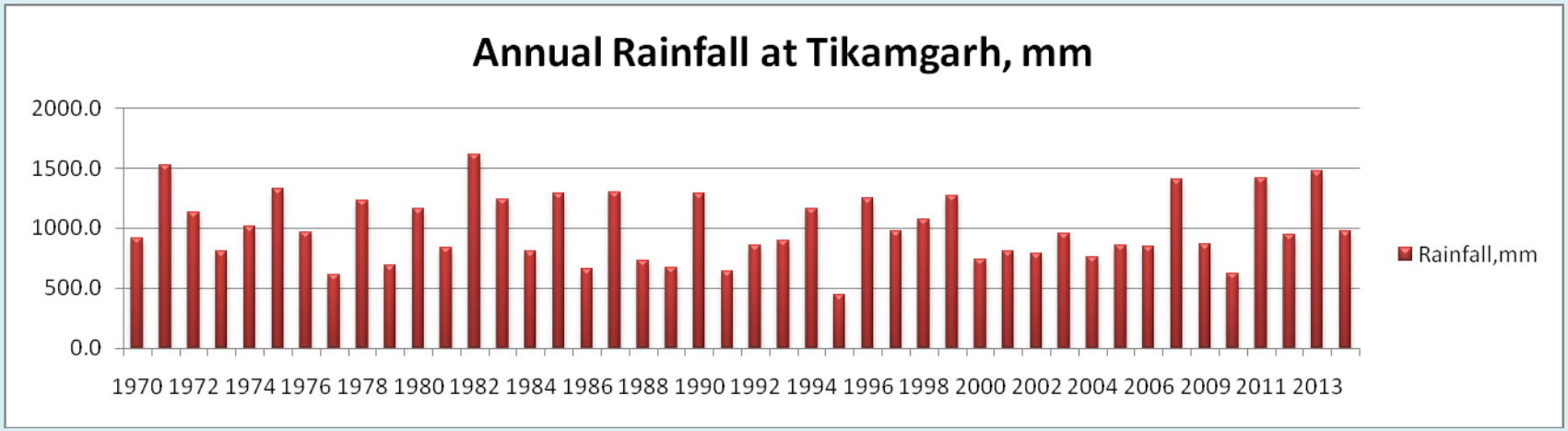
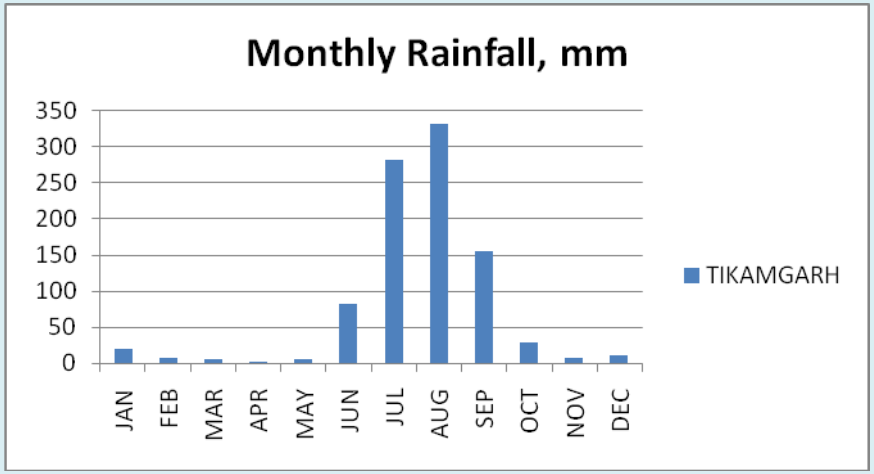


Fig. 43C Rainfall analysis at district Shivpuri, Agro-Climatic Zone –VII, Bundelkhand





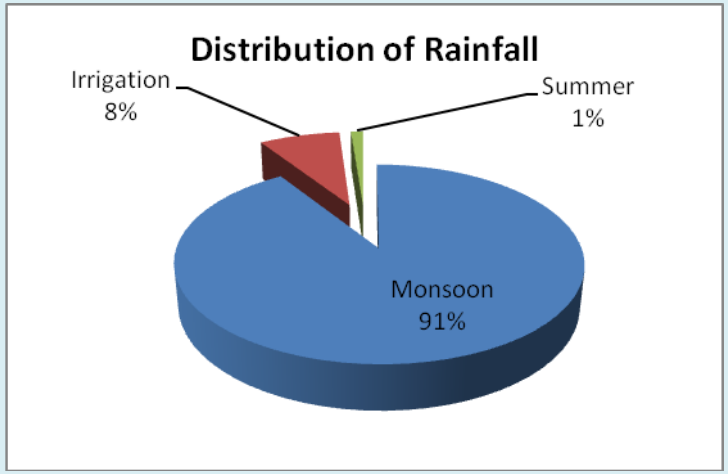


Fig. 43D Rainfall analysis at district Tikamgarh, Agro-Climatic Zone –VII, Bundelkhand

dogs, rabbits, fowls, ducks, turkey and other poultry. The indigenous cattles are about 50 times more than the cross breed cattle and Shivpuri district has maximum percentage (3.1%) of cross breed cattle followed by Tikamgarh and Chhatarpur. This indicates that the zone has tremendous scope for breeding improvement programmes. The sheep is mostly populated in Shivpuri and Tikamgah districts as these are contributing as much as more than 91 % of zonal population (94666). Goat is also reared in good quantity in the zone and in the zonal total of 882934 districts Chhatarpur, Datia, Shivpuri and Tikamgarh are in the proportion of 2.5:1:3:2.2. Other common animal of the zone is Fowls (241784), dogs (44386) and pigs (23918). Fowls are mostly populated in Chhatarpur and Tikamgarh district (67%) s. The zone has only numeric numbers of animals like rabbits, mules, camels, horses and donkeys.

Water requirement of crops

The zone is Wheat - Jowar zone has 682952 ha under wheat which is well distributed in the different districts. Zonal area of the jowar is 12617 ha only which is mostly concentrated in Chhatrpur district (82%). Barley is taken in 38477 ha and major area lies in Chhatarpur and Tikamgarh (83%). 83% of total zonal area of the maize (17681 ha) is under Shivpuri. Chhatrpur and Shivpuri in total contribute more than 83 % area of gram. Pulses other than pigeon pea are taken in 213397 ha Chhatarpur and Tikamgarh together contributes more than 80%. Rapeseed and Mustard are cultivating in 91254 ha where Shivpuri contributes in 36 %. Share of Shivpuri in soyabean in terms of coverage is 55%. Of zonal total of 336880 ha. Table 27A-B. Based on growing period, crop coefficient values, the water requirement of all the crops were worked out and presented in Table 27A. Figure 44-46 depicts crop water requirement of major crops in the districts of the zone.

Chilli (2672 ha), Coriander (1865 ha), Potato (4173 ha) and Onion (3188 ha) are the major specified vegetables in the zone (Table 27B). Chhatrpur with Tikamgarh together covers 82.7% area of Chillies. Shivpuri dominates (54.3 %) in Coriander cultivation. Chhatarpur and Tikamgarh together dominates in Potato (77.0%) and also in other vegetables (80.6%) in rabi. Total zonal area under other vegetables in kharif and rabi are respectively 12124 ha and 9029 ha.

Table 27 A : Water requirement of field crops in Bundelkhand, ha m

Crops	Chhatarpur		Datia		Shivpuri		Tikamgarh	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Rice	5369	4301	12141	9689	14634	11722	11414	9143
Jowar (Kharif)	10340	5329	1216	620	40	21	1021	526
Jowar (Rabi)	831	388	0	0	0	0	0	0
Bajra	73	32	806	345	5336	2306	0	0
Maize	530	300	694	388	14745	8335	1712	968
Ragi	0	0	0	0	0	0	0	0
Wheat	192585	111288	136121	79059	195611	113037	158635	91670
Barley	19960	11010	3434	1904	3101	1711	11982	6609
Other Cereals and Millets (Kharif)	108	56	0	0	55	29	194	101
Other Cereals and Millets (Rabi)	0	0	0	0	0	0	0	0
Gram	93687	49832	17407	9306	87837	46721	19670	10462
Arhar (Tur)	9785	6162	219	137	874	550	61	38
Other Pulses (Rabi)	21875	10917	24148	12113	6725	3356	13150	6563
Other Pulses (Kharif)	79607	40172	11922	5994	30155	15217	91713	46281
Sugarcane	551	751	5908	8035	952	1297	379	516
Groundnut	11054	6432	6599	3799	95391	55506	20017	11647
Castor seed		0	0	0	0	0	0	0
Sesamum	69322	37481	20899	11257	9976	5394	30129	16290
Rapeseed and Mustard	21036	10713	14595	7465	33360	16989	22263	11337
Linseed	6885	3662	0	0	39	21	37	20
Soyabean	88287	38162	1769	757	186224	80495	60600	26194
Niger seed	0	0	0	0	0	0	0	0
Sunflower	0	0	0	0	0	0	0	0
Safflower	0	0	0	0	0	0	0	0
Other Oilseeds	9	5	1361	815	121	73	0	0
Cotton	0	0	0	0	0	0	0	0
Jute	0	0	0	0	0	0	0	0
Mesta	0	0	0	0	0	0	0	0
Sanhemp	685	610	275	244	14	12	7	6
Other Fibres	0	0	0	0	0	0	0	0

Table 27 B : Water requirement of field crops in Bundelkhand, ha m

Crops	Chhatarpur		Datia		Shivpuri		Tikamgarh	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Chillies	1133	1239	75	82	388	424	1076	1177
Ginger	910	1145	25	31	31	39	1152	1450
Turmeric	102	128	4	5	0	0	205	257
Betel nut	0	0	0	0	0	0	0	0
Garlic	176	289	27	44	297	488	151	248
Coriander	536	779	19	28	1014	1473	296	430
Other Condiments and Spices	46	57	0	0	3	4	81	100
Mango	22	36	1	2	5	8	0	0
Banana	1	2	0	0	0	0	0	0
Citrus Fruits	8	11	0	0	23	30	68	90
Grapes	0	0	0	0	0	0		0
Papaya	34	57	5	8	7	12	75	126
Other Fruits	32	53	8	13	93	153	177	291
Potato	1660	1530	302	278	655	604	1556	1434
Sweet Potato	454	327	3	2	101	73	509	367
Onion	1047	1821	162	282	1310	2279	669	1164
Other Vegetables (Kharif)	4177	3011	583	419	3170	2285	4194	3023
Other Vegetables (Rabi)	4263	3023	892	636	854	606	3020	2142
Opium	0	0	0	0	0	0	0	0
Tobacco	53	33	0	0	0	0	0	0
Other Plantation Crops	8112	14896	0	0	863	1585	17	31
Fodder Crops	5776	4241	6336	4635	0	0	11181	8210
Other Non Food Crops	2	3	551	719	1	1	0	0

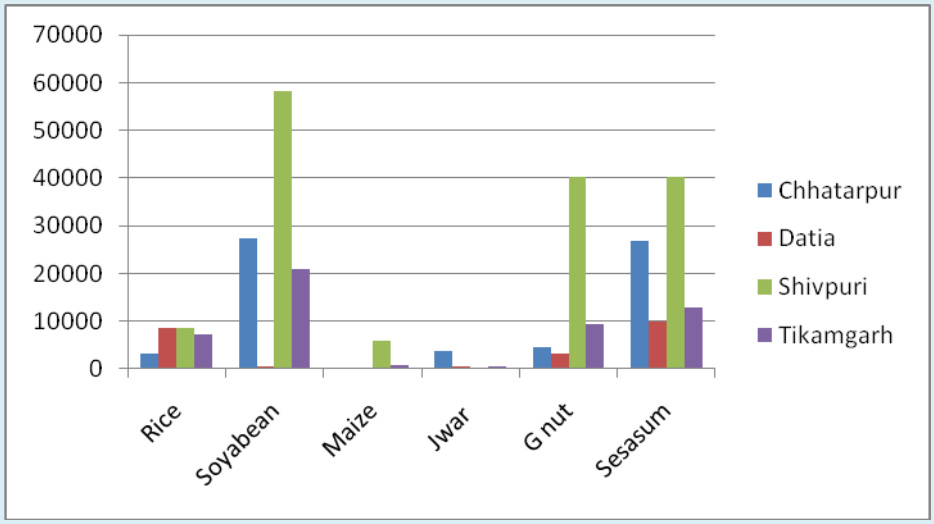


Fig. 44 Crop water requirement of major kharif crops of ACZ VII-Bundelkhand region in ha m

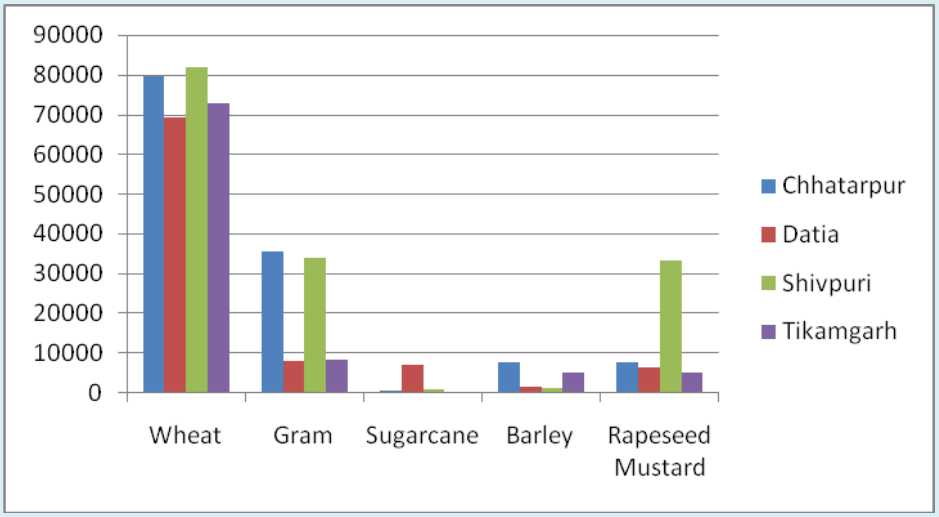


Fig. 45 Crop water requirement of major rabi crops of ACZ VII -Bundelkhand region in ha m

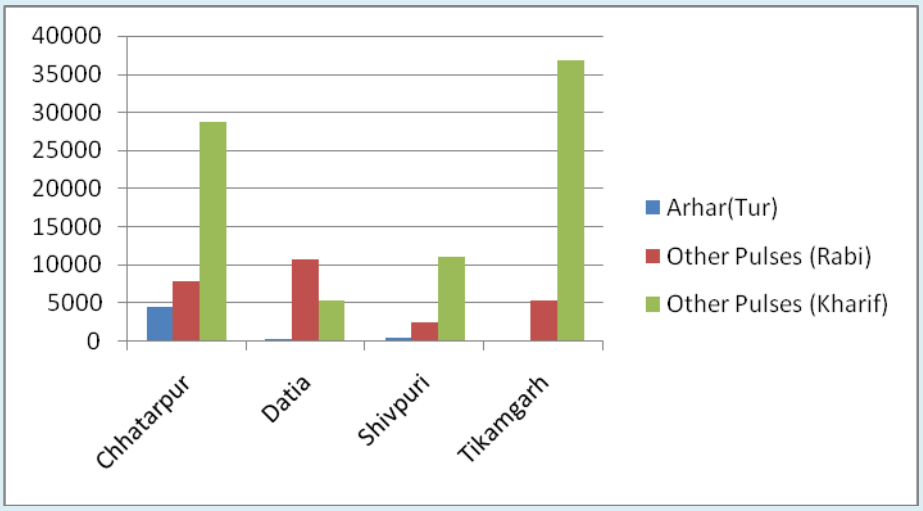


Fig. 46 Crop water requirement of pulse crops of ACZ VII -Bundelkhand region in ha m

Water budget

The agroclimatic zone VII (ACZ VII)- Bundelkhand receives total quantum of water towards rainfall as 2557033 ha-m. Maximum (36.9 %) of it receives in district Chhatarpur followed by Shivpuri (31.4 %), Tikamgarh (21.1 %) and Datia (9.3 %). National Commission on Agriculture has laid down norms for water budgeting of an area and as per its estimate the losses of water as evaporation, surface water flow and ground water flow out of the area is calculated in present estimation. Similarly, addition of water into the area as runoff generated from the zone, addition of soil moisture and to the ground water is also computed. The water budget so generated for ACZ VII is presented in Table 28. The immediate evaporation loss that occurs during the rainfall is taken as 17.5% of total rainfall and it is 447481 ha-m for the zone. 28.7% rainfall converts into surface flow and it is 733868 ha m. It is considered that 10.549 % (121918 ha-m) of surface flow goes out of the zone. Ground water also adds to the surface flow and it is taken as 23.739% of surface flow. Thus, surface flow arrives to be 1155728 ha-m which is 45.198% of total precipitation.

Evaporation takes place from open water body, soil surface, forest and vegetation and also from rise of water table, and, respectively it is taken as 7.916% (91487 ha-m) of total surface flow, 31.504% (358437 ha-m) of total soil moisture storage, 30.826% (350723 ha-m) of total soil moisture and 18.451% (101399 ha-m) of total ground water. Part of rainfall as recharge enriches ground water and it is 12.5% (319629 ha-m). There is an addition to the ground water from streams and flood flows which is -4.851 % (-56064 ha-m) of total surface flow. The total utilizable surface and ground water for the ACZ- VII computed as 735932 ha-m.

The soil moisture increases due to rainfall as well as from irrigation. 41.3% of rainfall and 7.067% of total surface flow is considered as soil moisture storage. Total zonal soil moisture storage is 1137752 ha-m and out of this 428625 ha-m is available as ET for the crops. Each and every district of the ACZ VII zone contributes in same proportion in zonal water budgeting as the quantum of rainfall of each district contributes in zonal rainfall quantum owing to rainfall based water distribution.

Utilization of water takes place in four major categories. These are, domestic and animal water needs, crop water requirement and requirement of water for industrial and recreation.

Table 28 : Water budgeting of Bundelkhand, ha-m

S.N	Particulars	Chhatarpur	Datia	Shivpuri	Tikamgarh	Zone Total
1	Normal rainfall, ha-m	945110	269175	803315	539433	2557033
2	Immediate evaporation (17.5%)	165394	47106	140580	94401	447481
3	Surface flow (28.7%)	271247	77253	230551	154817	733868
4	From outside state(10.549% of total surface flow)	45062	12834	38302	25720	121918
5	To GW from flood flows (-4.851% of total surface flow)	-20722	-5902	-17613	-11827	-56064
6	From GW to surface flow(23.739% of total surface flow)	101406	28881	86192	57879	274358
7	From irrigated area to surface flow(7.067% of total surface flow)	30188	8598	25659	17230	81675
8	Total surface flow(45.198% of total ppt)	427171	121662	363082	243813	1155728
9	Evaporation losses from reservoirs and tanks (7.916% of total surface flow)	33815	9631	28742	19300	91487
10	Flow into seas and outside state (43.445% of total surface flow)	185584	52856	157741	105925	502106
11	Utilizable surface flow (48.639% of total surface flow)	207772	59175	176600	118588	562134
12	Water available for ground water storage (12.5%)	118139	33647	100414	67429	319629
13	From streams and flood flows to GW(4.851% of total surface flow)	20722	5902	17613	11827	56064
14	From irrigation to GW addition (S.N.15-(12+13))	64262	18302	54621	36678	173864
15	Total GW (21.492% of total ppt)	203123	57851	172648	115935	549558

16	Evaporation and rise of water table (18.451% of total GW)	37478	10674	31855	21391	101399
17	Regeneration into streams(49.924% of total GW)	101407	28882	86193	57879	274361
18	GW available utilization(31.625% of total GW)	64238	18295	54600	36664	173798
19	Total utilizable surface + GW (S.N. 11+18)	272009	77470	231200	155253	735932
20	Soil moisture storage (41.3% of normal rainfall)	390330	111169	331769	222786	1056055
21	From irrigated area to soil moisture(7.067% of total surface flow)	30188	8598	25659	17230	81675
22	Total soil moisture storage (44.495% of total ppt)	420527	119769	357435	240021	1137752
23	Evaporation losses from soil moisture (31.504% of total soil moisture storage)	132483	37732	112606	75616	358437
24	Evap. losses from forest and other veg. (30.826% of total soil moisture)	129632	36920	110183	73989	350723
25	Soil moisture available for ET from crops (37.673 % of total soil moisture)	158425	45121	134656	90423	428625
26	Water requirement of crops	264980	139464	270218	205884	880546
27	Water requirement of animal husbandry	5863	2666	9190	6004	23723
28	Domestic water requirement	8686	3875	8504	7120	28185
29	Industrial Water requirement @ 6 % of available fresh water	45358	15653	52388	26589	139988
30	Water available for utilization (S.N. 19+25)	430434	122591	365856	245676	1164557
31	Water required for different sectors (26+27+28+29)	324887	161658	340300	245597	1072442
32	Surplus or deficit of water in the district (30-31)	105547	-39067	25556	79	92115

A water need of different sectors in districts of ACZ VII is presented in Fig. 47. Total crop water requirement of the zone is 880551 ha m and out of which Shivpuri needs maximum water towards crops as it has 30.7 % of zonal total. The least crop water demand comes from Datia district (15.8 %). In comparison to the crop water demand the water demand towards domestic and animal husbandry is very low as it is respectively 28185 ha m and 23724 ha m. Owing to more population in Chhatarpur and Shivpuri, the domestic demand is about 61 % of the zonal demand. Datia registers the least domestic water demand i.e. only 13.7 %. The Shivpuri has more animal husbandry and demand for 38.7 % of the zonal animal water needs. The industrial demand is computed as 6% of available water thus total zonal demand comes out as 139988 ha m.

Total water needs and supply of different districts of ACZ VII is presented in Fig. 48. The excess of water is also shown in the figure. The water available for utilization at zonal level is 122801 ha m and almost of it lies with Chhatrpur district. Datia and Tikamgarh are using more water than the available therefore these are in deficit. An abstract in pictorial form is provided in Fig 49.

Taking net sown area of these district, as per Directorate of Extension and Farmers Welfare, 466626 ha, 211563 ha, 227160 ha, 458027 ha, and 278379 ha, the per hectare water availability due to this surplus water comes out to be 40 cm, - 28 cm, 16 cm, and - 1 cm. It means, the future plans to enhance crop production or alternate cropping may be based on this much depth of available water.

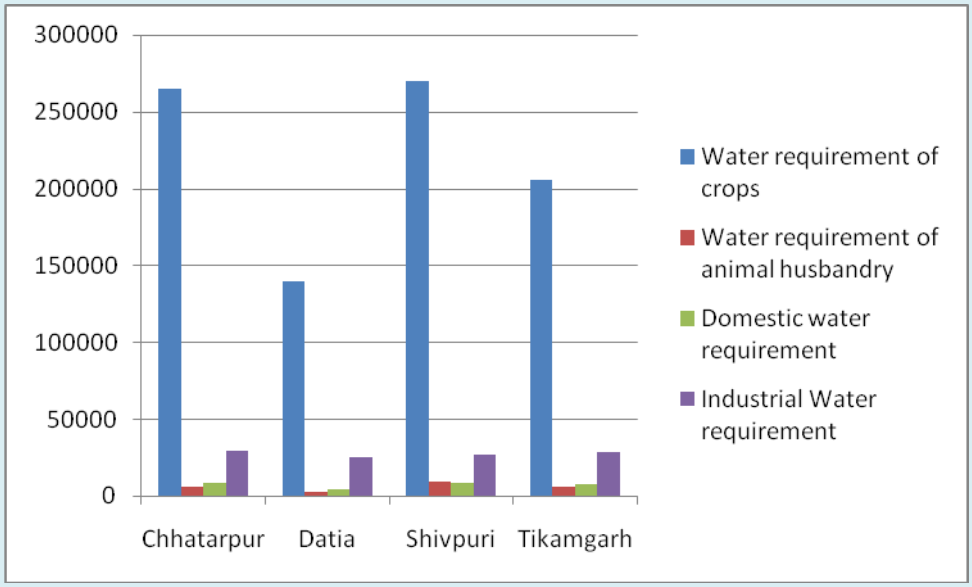


Fig. 47 Water needs of different sectors in districts of ACZ VII - Bundelkhand (ha-m)

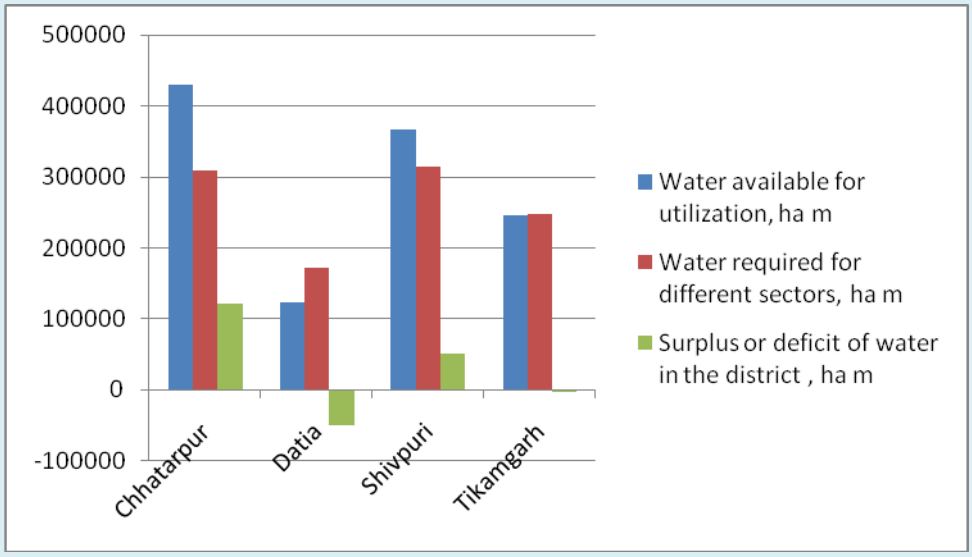


Fig. 48 Total Water needs and supply of different districts of ACZ VII - Bundelkhand (ha-m)

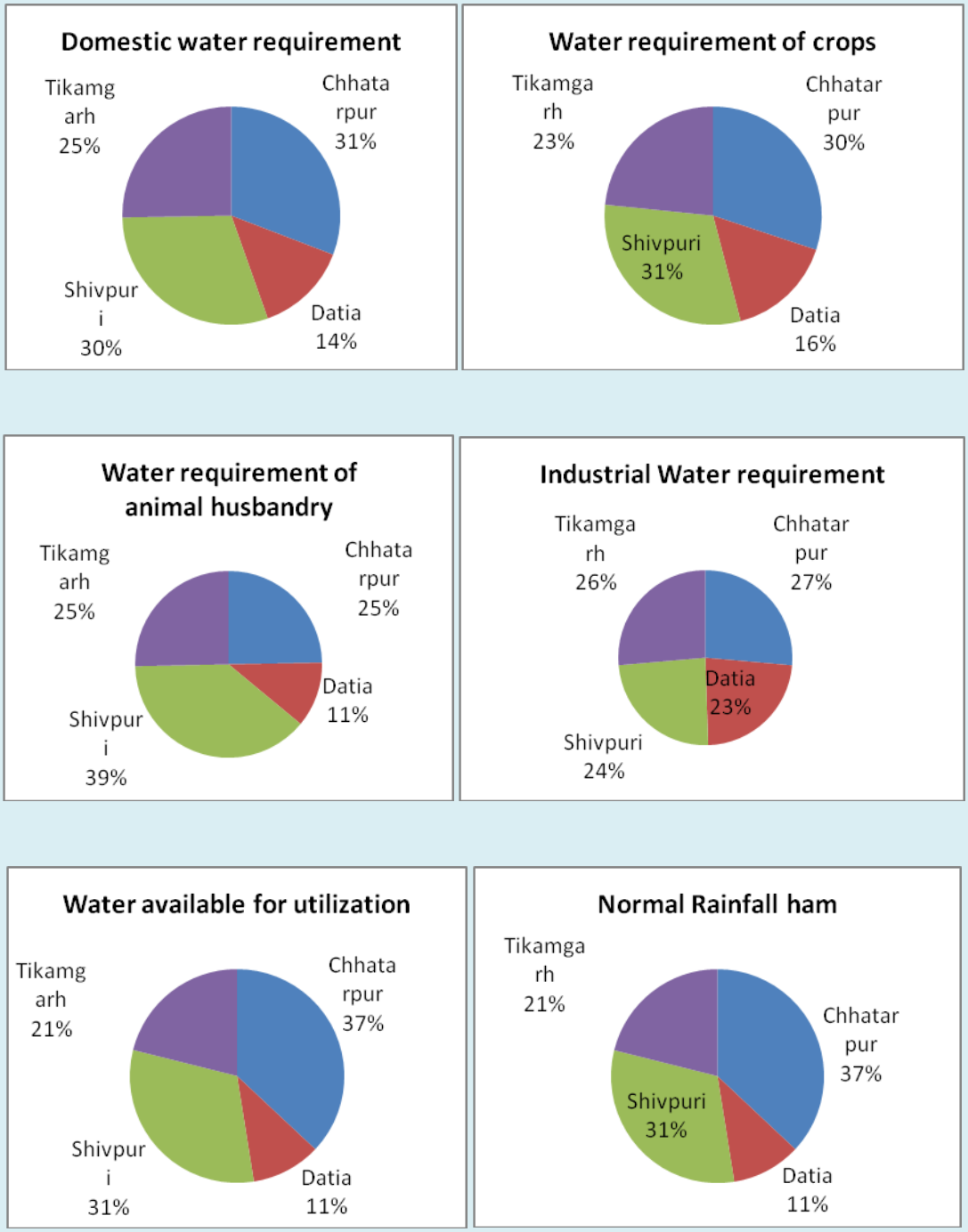


Fig. 49 Abstract of water of different districts of ACZ VII - Bundelkhand (ha-m)

Agroclimatic Zone VIII - Satpura Plateau

The Agroclimatic zone VIII – Satpura Plateau has two districts namely Chhindwara and Betul. It comes under Wheat – Jowar zone having shallow black (medium) soils. The zone has total geographical area of 2192723 ha, out of which forest area is 39.9 %. Net area sown is 43.4 %. Out of total Net Sown area of 952071 ha, the fallow land including current fallow is 7.4 %. District land utilization is presented in Table 29.

Rainfall analysis

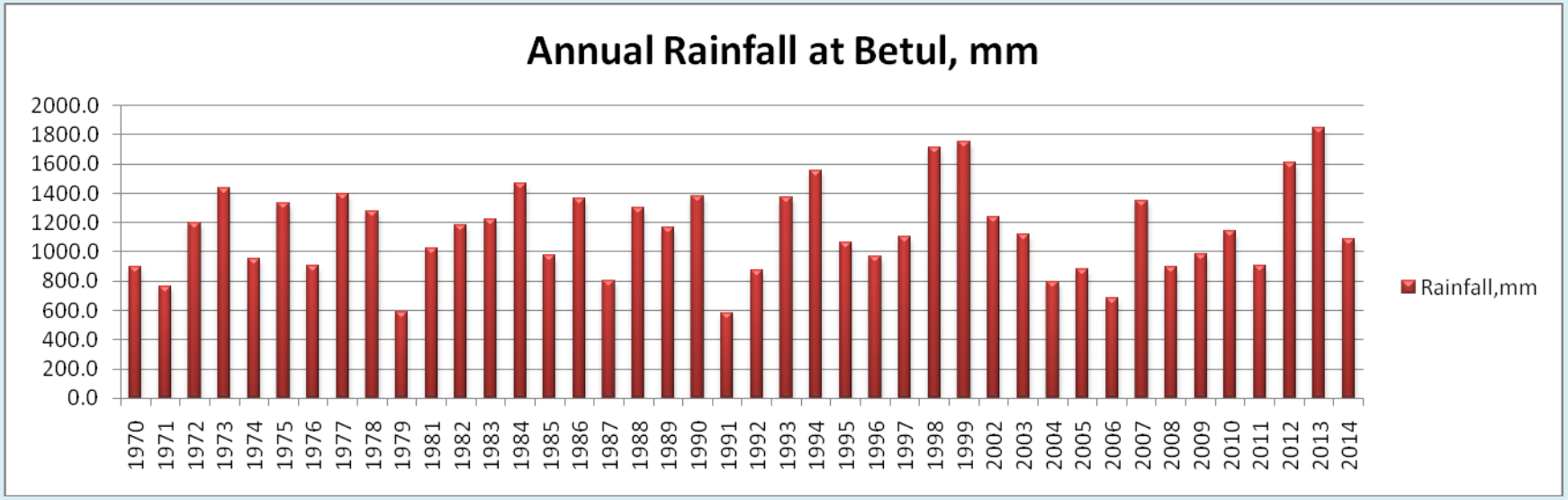
Annual normal rainfall is 1000 to 1200 mm. On an average 88 % of this rainfall occurs during monsoon i.e. June to September, 10% in winter i.e. late December and 2 % in summer. Maximum rainfall occurs in the month of August followed narrowly by the month July. The pattern of annual rainfall occurred in years 1970 to 2014 is presented in Fig. 50A-B. The record also shows maximum ever rainfall of 1830 mm (2013) was occurred in the Betul. The annual rainfall exceeded 50.1% and 32.3% times than the normal annual rainfall in Chhindwara and Betul districts respectively.

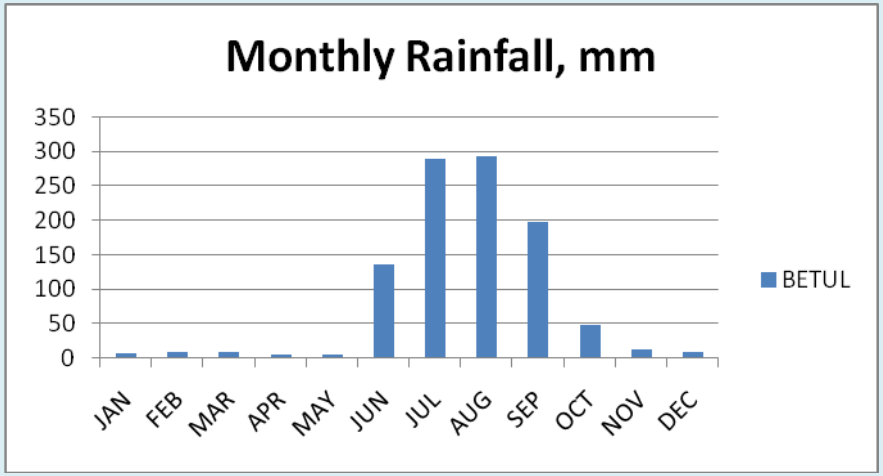
Domestic and livestock water needs

Total population of the zone is 3665553 as per Census 2011. Total human water needs of the zone is 18062 ha-m. Table 30 illustrates water requirement towards human needs as well as for live stock. Live stock population comprises of cattle both cross breed and indigenous, buffalo, bovine, sheep, goat, horses and ponnies, mules, donkey, pigs, dogs, rabbits, fowls, ducks, turkey and other poultry. The indigenous cattles are about 26 times more than the cross breed cattle. Almost equal in numbers the cross breed cattles are found in both the districts however 57.3% of total indigenous cattles (1179132) are found in Chhindwara. Chhindwara has more population of all major animal type than Betul. For animal types ; Buffalo, Bovine, Goat, Pigs and Fowls it is respectively 53%, 56%, 65%, 61% and 64% in favour of Chhindwara where these are totaling at zonal levels respectively as 257091, 1482211, 418284, 30272 and 506995. Other animals are of only numeric value.

Table 29 Total Area and Classification of Area In Each District of Satpura Plateau MADHYAPRADESH State for the year ending 2013- 14															
				Not Available For Cultivation			Other Uncultivated Land Excluding Fallow Land			Fallow Land					
DISTRICT NAME	Reporting Area For Land Utilization Statics	Forests	Area Under Non Agricultural Uses	Barren and Unculturable Land	Total	Permanent Pastures and Other Grazing Lands	Land Under Misc Tree crops and Groves not Included in Net Area	Culturable Waste Land	Total	Fallow Lands Other than Current Fallows	Current Fallows	Total	Net Area Sown	Total Cropped Area	Area Sown more than once
(1)	(2)	(3)	(4)	(5)	6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
BETUL	1007800	397390	46852	25942	72794	27791	4	38765	66560	22922	7558	30480	440576	604455	163879
CHINDWARA	1184923	477290	51329	20764	72093	53905	31	29949	83885	21663	18497	40160	511495	720374	208879
Total	**2192723**	**874680**	**98181**	**46706**	**144887**	**81696**	**35**	**68714**	**150445**	**44585**	**26055**	**70640**	**952071**	**1324829**	**372758**

Table 30 : Live stock and Human water needs of ACZ VIII			
	Betul	Chhindwara	Zone Total
Cross breed Cattle	22908	23080	45988
Water Req. (l/day)	3436200	3462000	6898200
Indigenous Cattle	503145	675987	1179132
Water Req. (l/day)	50314500	67598700	117913200
Buffalo	120395	136696	257091
Water Req. (l/day)	18059250	20504400	38563650
Bovine	646448	835763	1482211
Water Req. (l/day)	96967200	125364450	222331650
Sheep	1703	56	1759
Water Req. (l/day)	17030	560	17590
Goat	145214	273070	418284
Water Req. (l/day)	1452140	2730700	4182840
Horse & Ponies	405	1032	1437
Water Req. (l/day)	13162.5	33540	46702.5
Mules	182	29	211
Water Req. (l/day)	5915	942.5	6857.5
Donkey	229	239	468
Water Req. (l/day)	7442.5	7767.5	15210
Camels	1	0	1
Water Req. (l/day)	115	0	115
Pigs	1052	1799	2851
Water Req. (l/day)	10520	17990	28510
Dogs	11882	18390	30272
Water Req. (l/day)	59410	91950	151360
Rabbits	144	118	262
Water Req. (l/day)	92.16	75.52	167.68
Elephants	97	51	148
Water Req. (l/day)	14550	7650	22200
Fowls	183022	323973	506995
Water Req. (l/day)	45755.5	80993.25	126748.75
Ducks	379	237	616
Water Req. (l/day)	94.75	59.25	154
Turkeys	5	0	5
Water Req. (l/day)	1.25	0	1.25
Other Poultry	87	6	93
Water Req. (l/day)	21.75	1.5	23.25





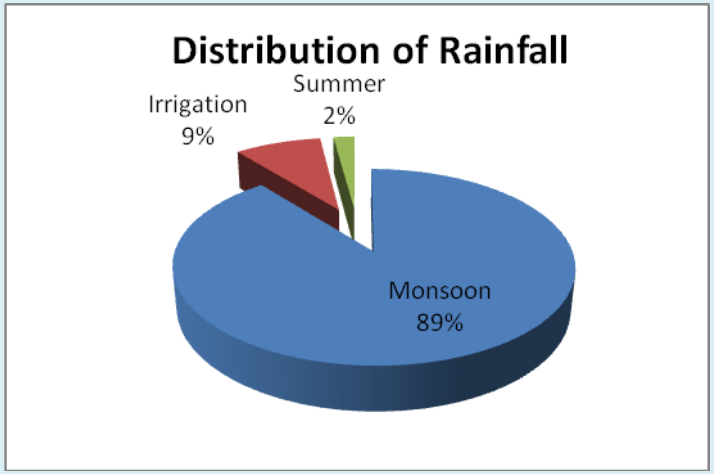
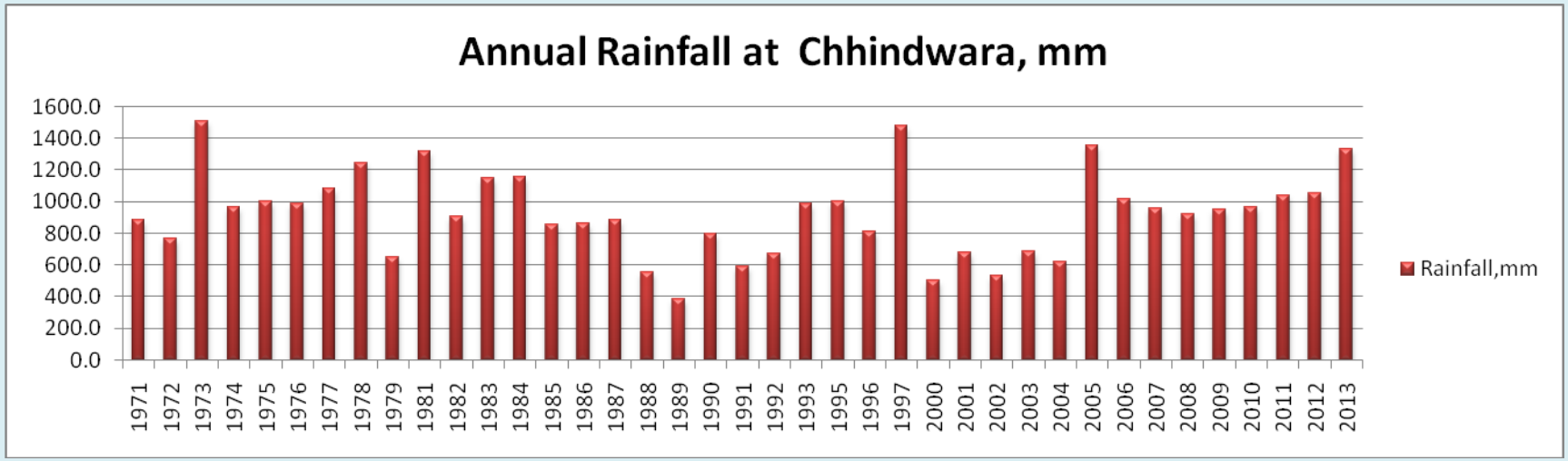
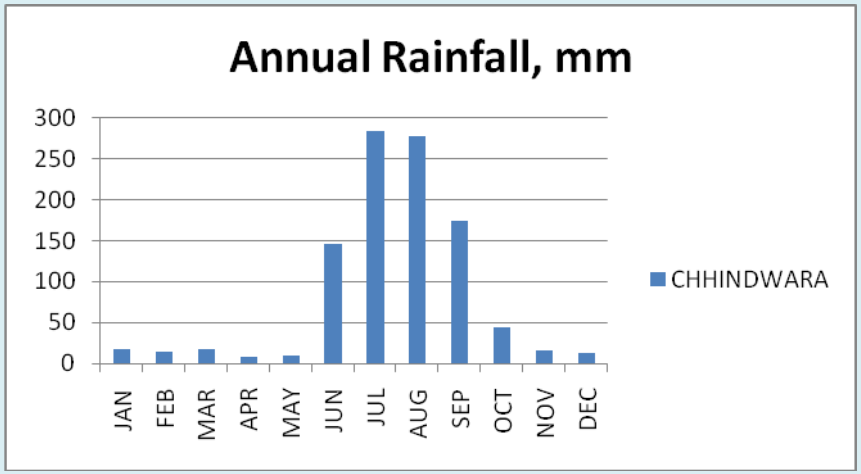


Fig. 50A Rainfall analysis at district Betul, Agro-Climatic Zone –VIII, Satpura Plateau





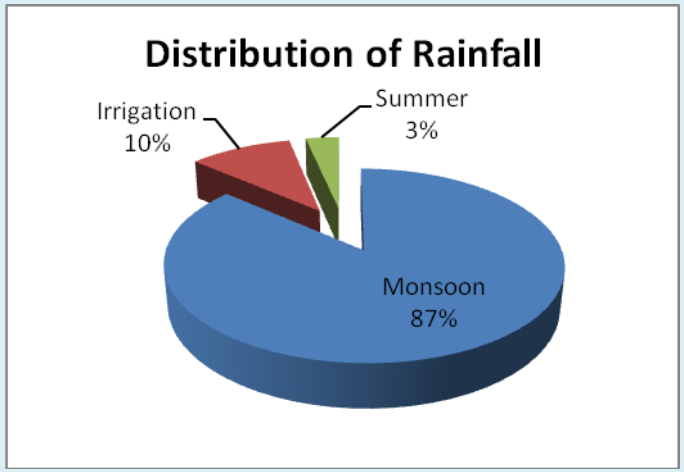


Fig. 50B Rainfall analysis at district Chhindwara, Agro-Climatic Zone –VIII, Satpura Plateau

Water requirement of crops

The zone is a Wheat- Jowar zone has 146144 ha under wheat and 42479 ha in Jowar with almost equal coverage in both the districts. Rice grown in 57652 ha at zone level but more than two third area covers in Betul. Ragi is also taken in 122803 ha in Betul. Maize is another main crop and cultivating in 208029 ha with two third areas falls in Chhindwara. Cultivating area of Gram and pigion pea is almost the same in both the districts. 77.6 % area of groundnut falls in Chhindwara district. Soyabean is taken in 391866 ha in the zone and out of this 62 % is in Betul district. Cotton is also growing in the zone but almost all is taken in Chhindwara district Table 31A-B. Based on growing period, crop coefficient values, the water requirement of all the crops were worked out and presented in Table 31A. However, based on irrigated area the water requirement of major crops were also calculated and presented Fig. 51 to Fig 53.

The zone is known for its vegetable cultivation as it has 4707 ha area under Chillies, 3767 ha in Ginger, 4771 ha in Garlic, 6127 ha in Potato, 2742 ha in Onion. Chhindwara dominates in Ginger (98.8%), Garlic (91.0%) and Onion (80.9%). This district also has domination in other vegetables in kharif and rabi, 79% and 82% respectively. Almost all citrus fruits (95.3%) are produced in Chhindwara district.

Water budget

The agroclimatic zone VIII (ACZ VIII)- Satpura Plateau receives total quantum of water towards rainfall as 2286506 ha-m. National Commission on Agriculture has laid down norms for water budgeting of an area and as per its estimate the losses of water as evaporation, surface water flow and ground water flow out of the area is calculated in present estimation. Similarly, addition of water into the area as runoff generated from the zone, addition of soil moisture and to the ground water is also computed. The water budget so generated for ACZ VIII is presented in Table 32. The immediate evaporation losses that occurs during the rainfall is taken as 17.5% of total rainfall and it is 400139 ha m for the zone. 28.7% rainfall converts into surface flow and it is 656227 ha-m. It is considered that 10.549 % (109019 ha-m) of surface flow goes out of the zone. Ground water also adds to the surface flow and it is taken as 23.739% of surface flow. Thus, surface flow arrives to be 1033455 ha-m which is 45.198% of total precipitation.

Table 31 A : Water requirement of field crops in Satpura Plateau, ha m

Crops	Betul		Chhindwara	
	Area	CWR	Area	CWR
Rice	43844	35645	13808	8740
Jowar (Kharif)	20309	10545	22170	8797
Jowar (Rabi)	-	-	-	-
Bajra	35	15	6	2
Maize	53778	30627	154251	67130
Ragi	122803	32807	-	-
Wheat	-	-	146144	79629
Barley	-	-	-	-
Other Cereals and Millets (Kharif)	4152	2194	23394	9625
Other Cereals and Millets (Rabi)	-	-	57	28
Gram	42475	24427	42935	21533
Arhar (Tur)	23549	15257	24775	12582
Other Pulses (Rabi)	5718	3085	10979	5166
Other Pulses (Kharif)	4851	2485	12589	5020
Sugarcane	10002	13955	12884	15152
Groundnut	5052	2962	17484	7833
Castor seed	-	-	48	51
Sesamum	482	265	822	351
Rapeseed and Mustard	413	227	394	186
Linseed	606	349	363	182
Soyabean	241852	105327	150014	49925
Niger seed	9370	7303	8912	5583
Sunflower	-	-	-	-
Safflower	-	-	19	7
Other Oilseeds	-	-	-	-
Cotton	214	179	34093	22368
Jute	-	-	-	-
Mesta	-	-	-	-
Sanhemp	40	35	181	129
Other Fibres	-	-	-	-

Table 31 B : Water requirement of fruits and vegetables crops in Satpura Plateau, ha m

Crops	Betul		Chhindwara	
	Area	CWR	Area	CWR
Chillies	2235	2625	2472	2453
Ginger	44	57	3723	3999
Turmeric	-	-	9	10
Betel nut	-	-	-	-
Garlic	427	718	4344	6229
Coriander	426	648	362	454
Other Condiments and Spices	-	-	6	7
Mango	64	108	8	11
Banana	-	-	-	-
Citrus Fruits	409	553	8313	9583
Grapes	-	-	-	-
Papaya	-	-	28	41
Other Fruits	79	133	56	80
Potato	1230	1163	4897	4051
Sweet Potato	346	253	420	239
Onion	523	931	2219	3369
Other Vegetables (Kharif)	1503	1100	5649	3218
Other Vegetables (Rabi)	2333	1789	10858	7261
Opium	-	-	-	-
Tobacco	-	-	-	-
Other Plantation Crops	-	-	2	3
Fodder Crops	5256	3917	591	343
Other Non Food Crops	35	48	95	107

Table 32 : Water budgeting of Satpura plateau

S.N	Particulars	Betul	Chhindwara	Zone Total
1	Normal rainfall, ha-m	1089734	1196772	2286506
2	Immediate evaporation (17.5%)	190703	209435	400139
3	Surface flow (28.7%)	312754	343474	656227
4	From outside state(10.549% of total surface flow)	51958	57061	109019
5	To GW from flood flows (-4.851% of total surface flow)	-23893	-26240	-50133
6	From GW to surface flow(23.739% of total surface flow)	116924	128408	245332
7	From irrigated area to surface flow(7.067% of total surface flow)	34808	38227	73034
8	Total surface flow(45.198% of total ppt)	492538	540917	1033455
9	Evaporation losses from reservoirs and tanks (7.916% of total surface flow)	38989	42819	81808
10	Flow into seas and outside state (43.445% of total surface flow)	213983	235001	448985
11	Utilizable surface flow (48.639% of total surface flow)	239566	263097	502662
12	Water available for ground water storage (12.5%)	136217	149597	285813
13	From streams and flood flows to GW(4.851% of total surface flow)	23893	26240	50133
14	From irrigation to GW addition (S.N.15-(12+13))	74096	81374	155470
15	Total GW (21.492% of total ppt)	234206	257210	491416

16	Evaporation and rise of water table (18.451% of total GW)	43213	47458	90671
17	Regeneration into streams(49.924% of total GW)	116925	128410	245334
18	GW available utilization(31.625% of total GW)	74068	81343	155410
19	Total utilizable surface + GW (S.N. 11+18)	313633	344439	658072
20	Soil moisture storage (41.3% of normal rainfall)	450060	494267	944327
21	From irrigated area to soil moisture(7.067% of total surface flow)	34808	38227	73034
22	Total soil moisture storage (44.495% of total ppt)	484877	532504	1017381
23	Evaporation losses from soil moisture (31.504% of total soil moisture storage)	152756	167760	320516
24	Evap. losses from forest and other veg. (30.826% of total soil moisture)	149468	164150	313618
25	Soil moisture available for ET from crops (37.673 % of total soil moisture)	182668	200610	383278
26	Water requirement of crops	194458	235971	430429
27	Water requirement of animal husbandry	6220	8027	14247
28	Domestic water requirement	7762	10300	18062
29	Industrial Water requirement @ 6 % of available fresh water	51901	57465	109366
30	Water available for utilization (S.N. 19+25)	496301	545049	1041350
31	Water required for different sectors (26+27+28+29)	260341	311763	572104
32	Surplus or deficit of water in the district (30-31)	235960	233286	469246

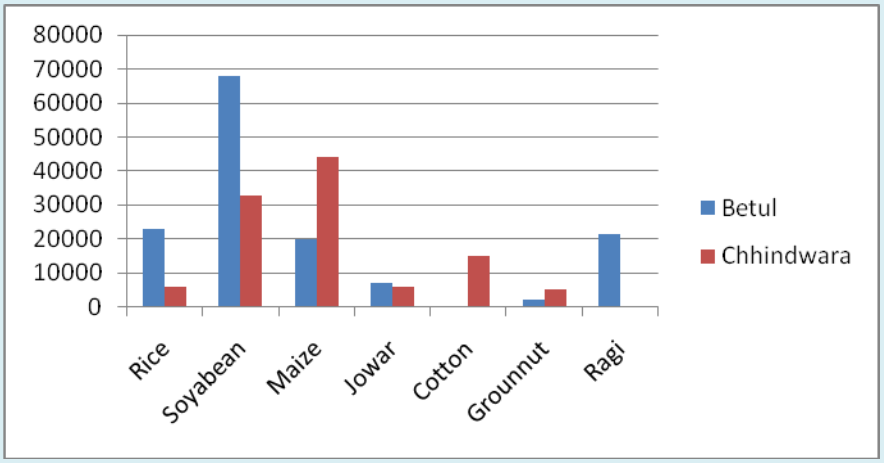


Fig. 51 Crop water requirement of major kharif crops of ACZ VIII -Satpura Plateau in ha m

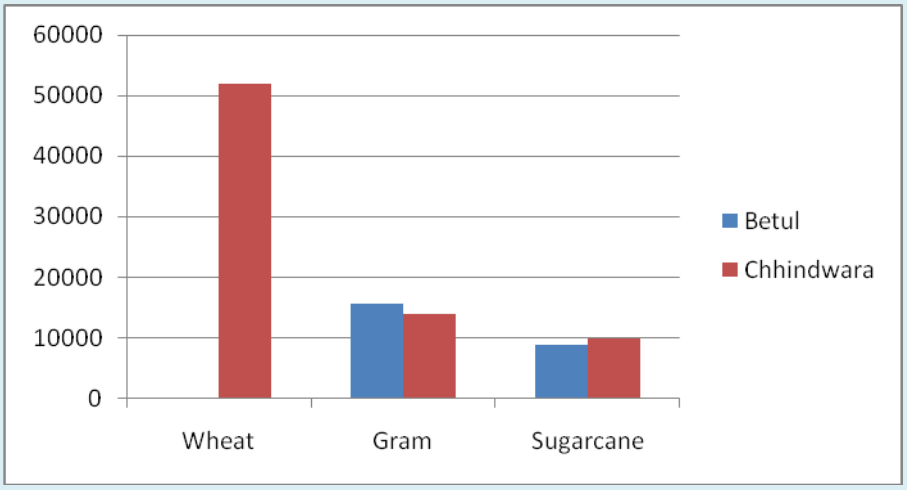


Fig. 52 Crop water requirement of major rabi crops of ACZ VIII -Satpura Plateau in ha m

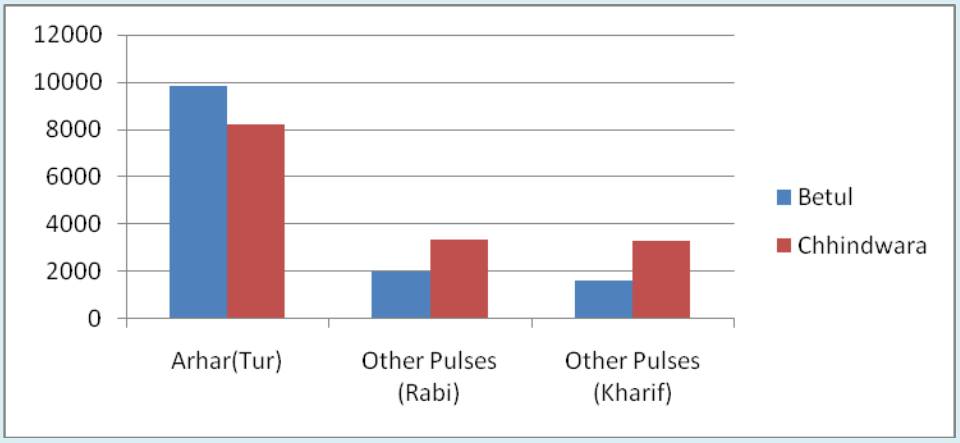


Fig. 53 Crop water requirement of pulse crops of ACZ VIII -Satpura Plateau in ha m

Evaporation takes place from open water body, soil surface, forest and vegetation and also from rise of water table, and, respectively it is taken as 7.916% (81808 ha-m) of total surface flow, 31.504% (320516 ha-m) of total soil moisture storage, 30.826% (313618 ha-m) of total soil moisture and 18.451% (90671 ha-m) of total ground water. Part of rainfall as recharge enriches ground water and it is 12.5 % (285813 ha-m). There is movement to ground water from streams and flood flows which is - 4.851 % (- 50133 ha-m) of total surface flow. The total utilizable surface and ground water for the ACZ VIII computed as 658072 ha-m.
The soil moisture increases due to rainfall as well as from irrigation. 41.3% of rainfall and 7.067% of total surface flow is considered as soil moisture storage. Total zonal soil moisture storage is 1017381 ha-m and out of this 383278 ha-m is available as ET for the crops.

Utilization of water takes place in four major categories. These are, domestic and animal water needs, crop water requirement and requirement of water for industrial and recreation. A water need of different sectors in districts of ACZ VIII is presented in Fig. 54. Total crop water requirement of the zone is 430430 ha-m. In comparison to the crop water demand the water demand towards domestic and animal husbandry is very low as it is respectively 18062 ha m and 14246 ha-m. The industrial demand is computed as 6% of available water thus total zonal demand comes out as 109366 ha-m.

Total water needs and supply of different districts of ACZ VIII is presented in Fig. 55. The excess of water is also shown in the figure. The water available for utilization at zonal level is 1041350 ha-m. As for as the excess water concerns the zone has 524525 ha-m of surplus water and this is 101 % of total utilization. Considering net sown area as 952071 ha the average depth of excess water available per hectare is 55 cm. At district level the per unit hectare water availability in Betul is 59 cm while it is 52 cm in Chhindwara district. It means, the future plans to enhance crop production or alternate cropping may be based on this much depth of water. An abstract in pictorial form is provided in Fig 56.

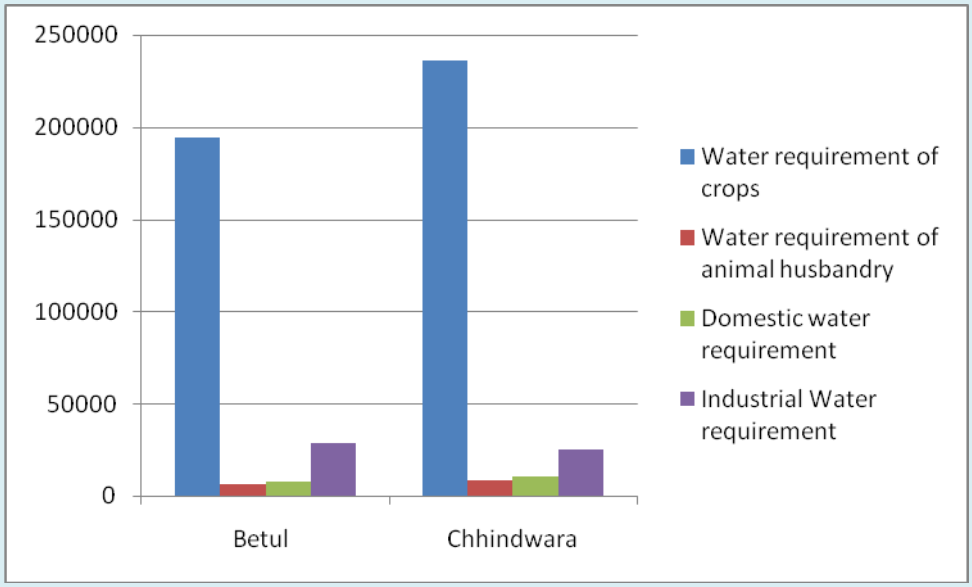


Fig. 54 Water needs of different sectors in districts of ACZ VIII - Satpura Plateau (ha-m)

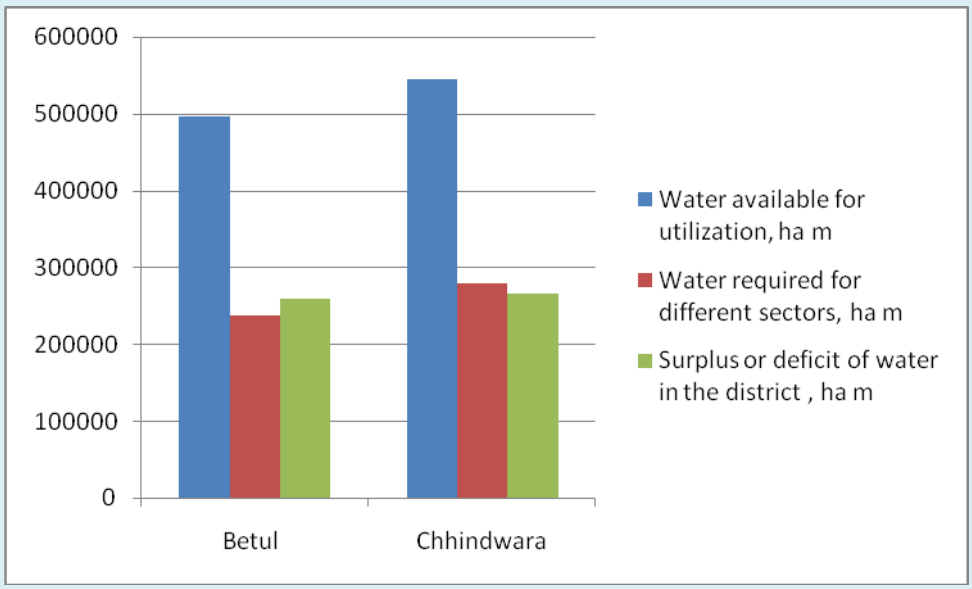


Fig. 55 Total Water needs and supply of different districts of ACZ VIII - Satpura Plateau (ha-m)

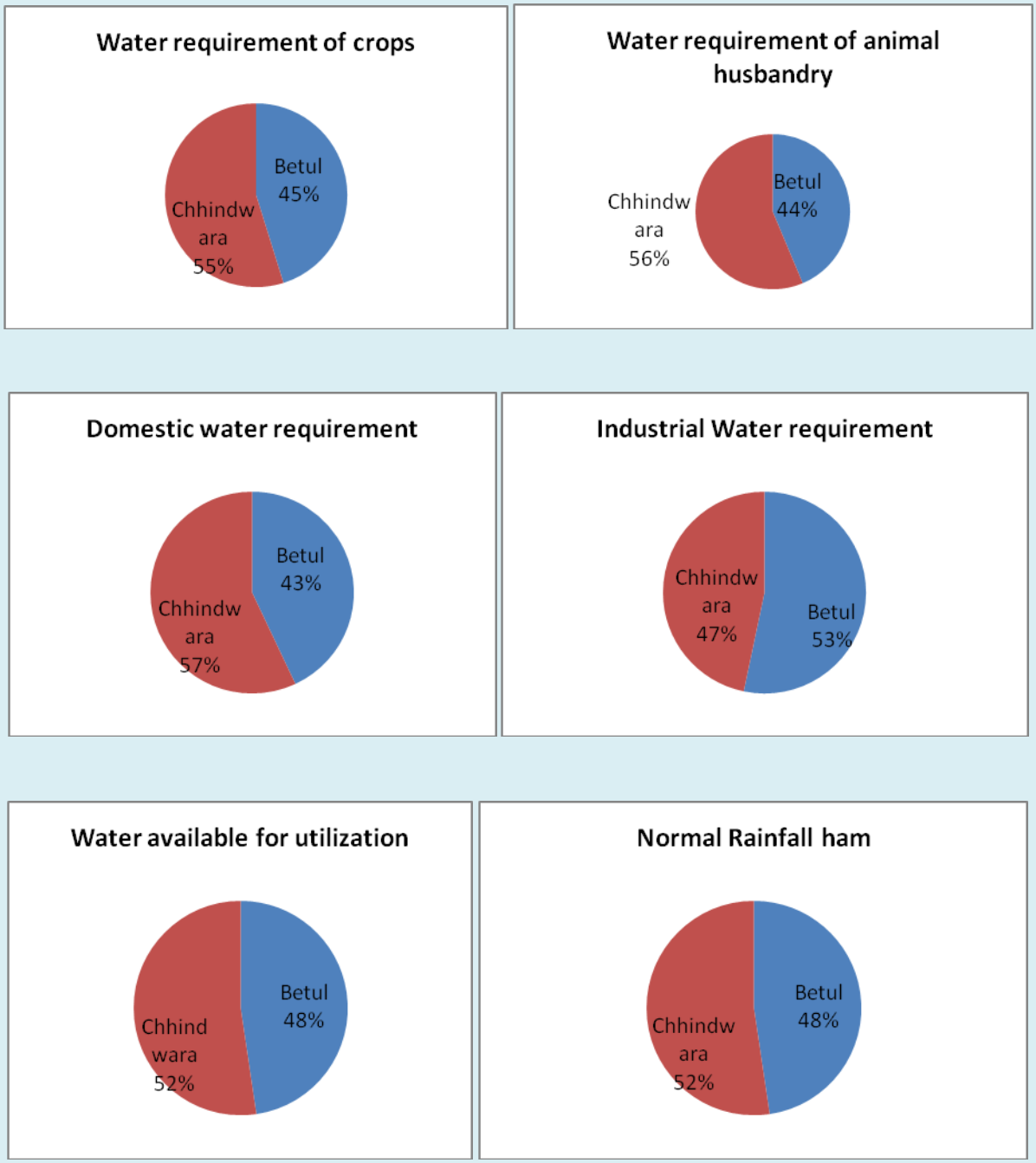


Fig. 56 Abstract of water of different districts of ACZ VIII - Satpura Plateau (ha-m)

Agroclimatic Zone IX - Malwa Plateau

The Agroclimatic zone IX – Malwa Plateau covers nine districts namely Agar Malwa, Dewas, Indore, Mandsaur, Neemuch, Rajgarh, Ratlam, Shajapur and Ujjain. It comes under Cotton- Jowar zone having medium black (medium) soils. The zone has total geographical area of 4360564 ha, out of which forest area is 10.4 % mostly in Dewas (45.4%) with negligible (2.0%) in Agar Malwa and Ujjain even when join together. Net area sown is 67.1% where three districts Dewas, Rajgarh and Ujjain together has zonal share of net area sown as 45.7%. Out of total net sown area of 2926767 ha, the fallow land including current fallow is 0.8 %. District wise land utilization is presented in Table 33.

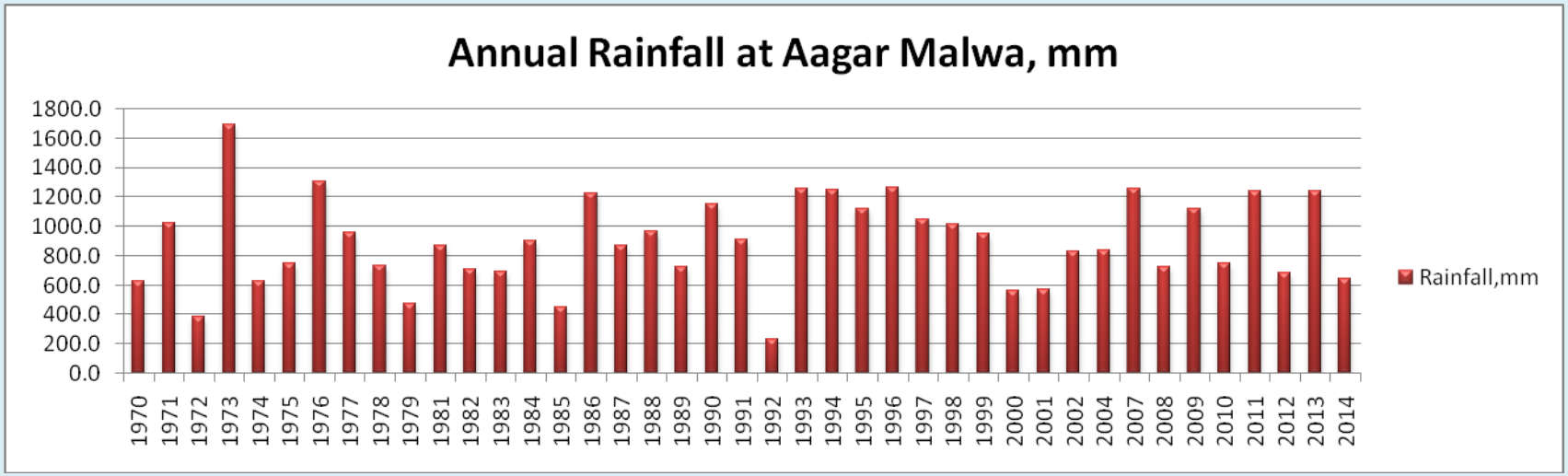
Rainfall analysis

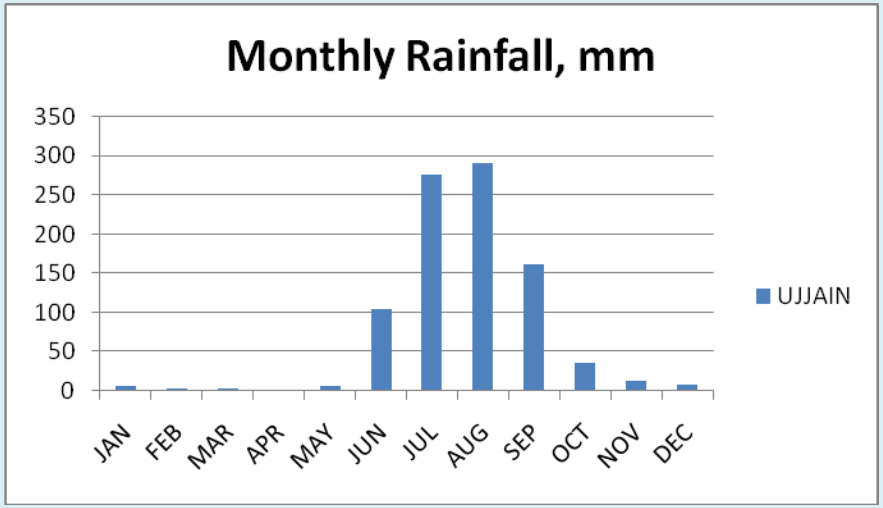
Annual rainfall ranges from 800 to 1000 mm. On an average 92 % of this rainfall occurs during monsoon i.e. June to September, 7% in winter i.e. late December and 1% in summer. Maximum rainfall occurs in the month of August except in Indore, Mandsaur and Neemuch. In these three districts maximum rainfall occurs in July which is slightly higher than rainfall that occurs in August. The patterns of annual rainfall occurred in different districts of Agroclimatic zone IX for years 1970 to 2014 are presented through Figures 57A-I. Mean annual rainfall of these districts are 927.0 mm, 1065.0 mm, 960.9 mm, 792.6 mm ,819.0 mm, 838.0 mm, 939.4 mm, 927.0 mm and 890.0 mm respectively for Agar Malwa, Dewas, Indore, Mandsaur, Nimuch, Rajgarh, Ratlam, Shajapur and Ujjain. The record also shows maximum ever rainfall of 2537 mm (1973) was occurred in Rajgarh. Rainfall of more than 2000 mm was also occurred in the same year in Dewas and Indore district. Except in year 1973 the annual rainfall never crosses 1600 mm mark. Respectively for these districts, the annual rainfall exceeded the normal annual rainfall by 52.9%, 29.4%, 26.5%, 58.8%, 35.2%, 38.2%, 50.0%, 55.9% and 50.0% times.

Domestic and livestock water needs

Total population of the zone is 13501206 as per Census 2011. Total human water needs of the zone is 66527 ha m where the Indore alone consumes 24.2% of zonal domestic water demand followed by Ujjain (14.7%) and Dewas (11.5%) districts. Neemuch district has minimum water needs of only 4070 ha-m.

Table 33 Total Area and Classification of Area In Each District of Malwa Plateau MADHYAPRADESH State for the year ending 2013- 14															
				Not Available For Cultivation			Other Uncultivated Land Excluding Fallow Land			Fallow Land					
DISTRICT NAME	Reporting Area For Land Utilization Statics	Forests	Area Under Non Agricultural Uses	Barren and Unculturable Land	Total	Permanent Pastures and Other Grazing Lands	Land Under Misc Tree crops and Groves not Included in Net Area	Culturable Waste Land	Total	Fallow Lands Other than Current Fallows	Current Fallows	Total	Net Area Sown	Total Cropped Area	Area Sown more than once
(1)	(2)	(3)	(4)	(5)	6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
AGAR MALWA	272578	6118	25074	30269	55343	22080	13	8016	30109	914	261	1175	179833	297742	117909
DEWAS	701307	206636	34907	12959	47866	44796	25	2074	46895	406	128	534	399376	728419	329043
INDORE	383097	52208	42028	9260	51288	17797	75	2294	20166	5340	2742	8082	251353	466632	215279
MANDSAUR	551806	40593	79534	43734	123268	13584	58	15208	28850	1008	906	1914	357181	625990	268809
NEEMACH	393555	94413	48382	39826	88208	9325	3	16880	26208	750	728	1478	183248	311079	127831
RAJGARH	616300	17636	44662	29019	73681	48806	251	30289	79346	4411	2124	6535	439102	783952	344850
RATLAM	486007	34341	40958	29787	70745	27234	110	14654	41998	919	491	1410	337513	577475	239962
SHAJAPUR	346040	21123	29438	10047	39485	17689	70	8971	26730	258	67	325	279500	501508	222008
UJJAIN	609874	3149	58788	5900	64688	32285	129	7635	40049	1792	535	2327	499661	938003	438342
Total	**4360564**	**455094**	**403771**	**210801**	**614572**	**233596**	**734**	**106021**	**340351**	**15798**	**7982**	**23780**	**2926767**	**5230800**	**2304033**





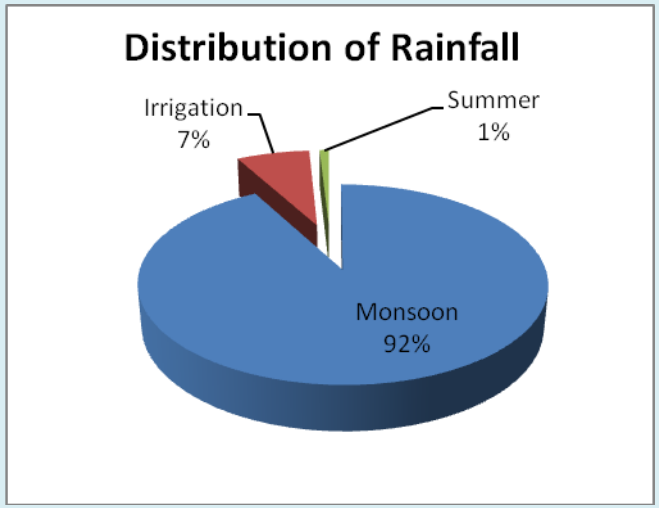
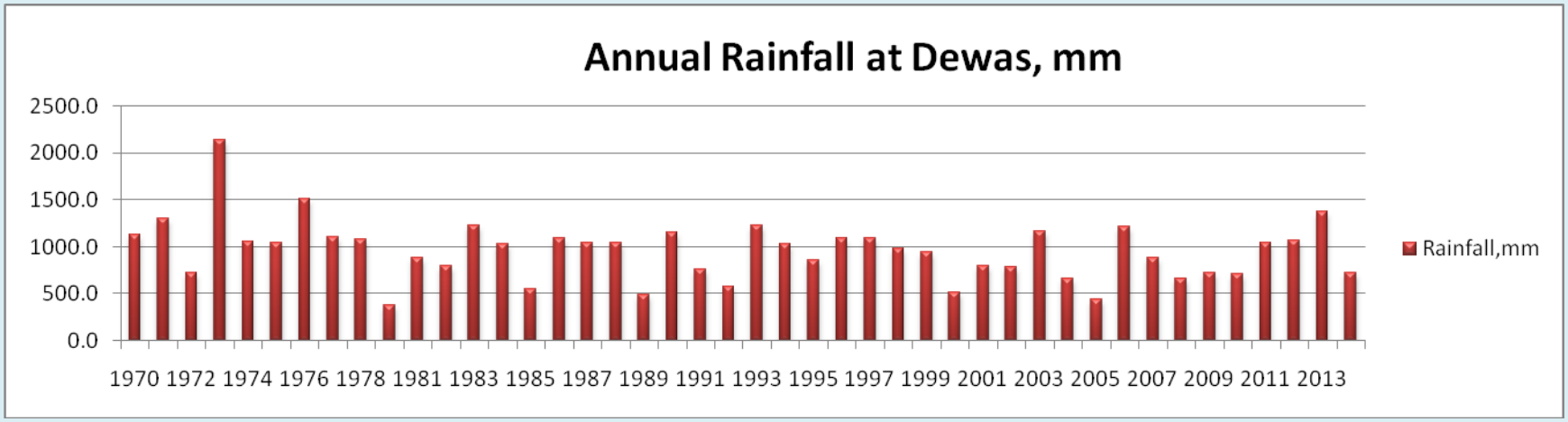
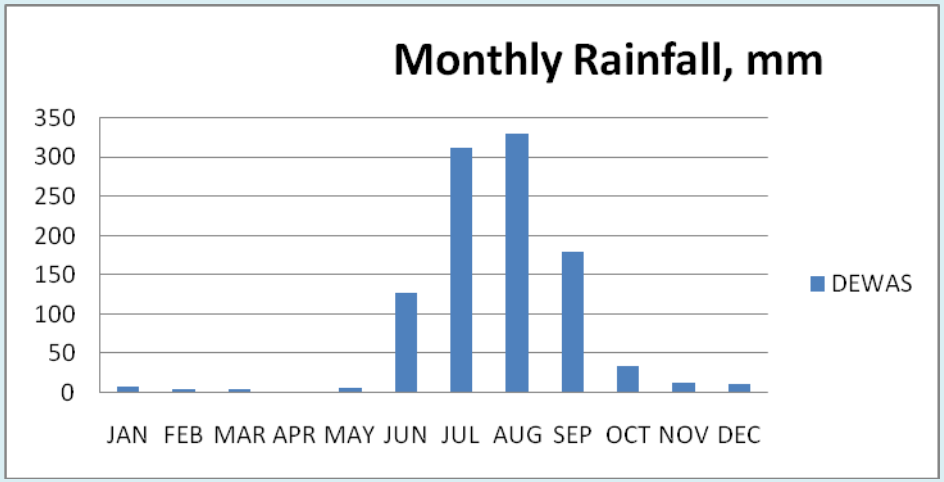


Fig. 57A Rainfall analysis at district Aagar-Malwa, Agro-Climatic Zone –IX, Malwa Plateau





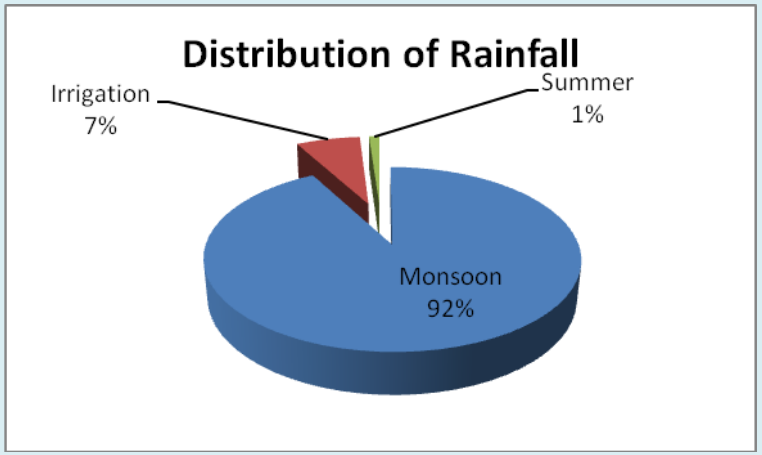
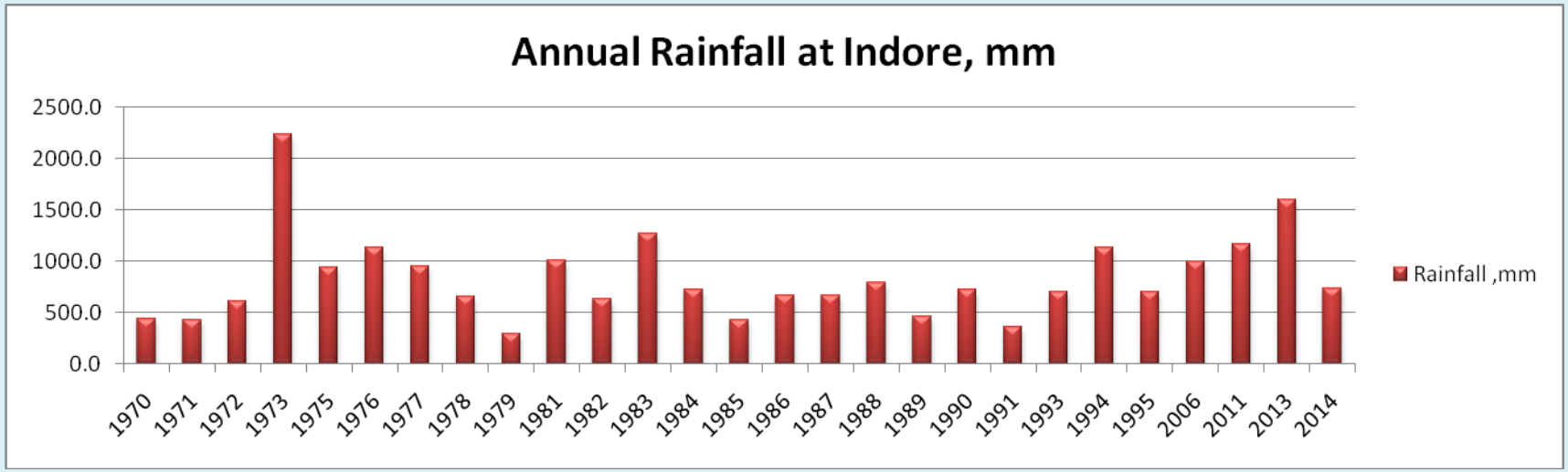
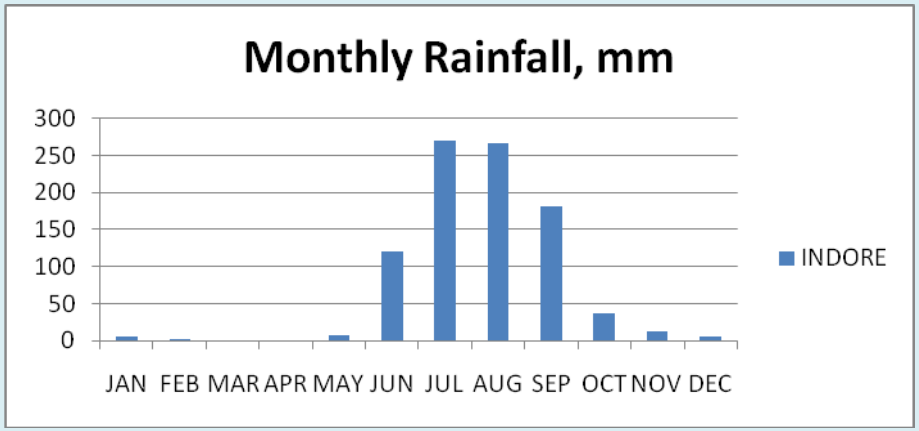


Fig. 57B Rainfall analysis at district Dewas, Agro-Climatic Zone –IX, Malwa Plateau





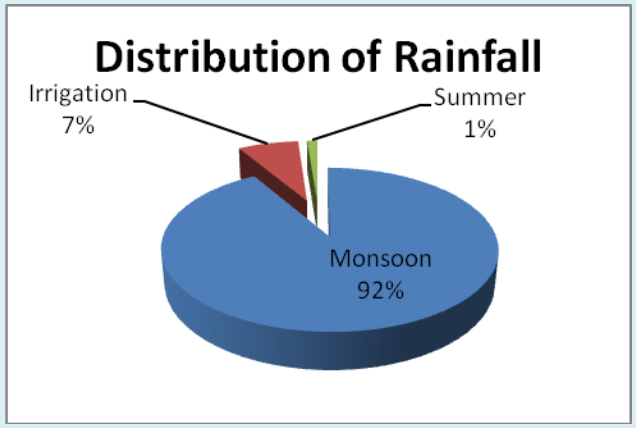
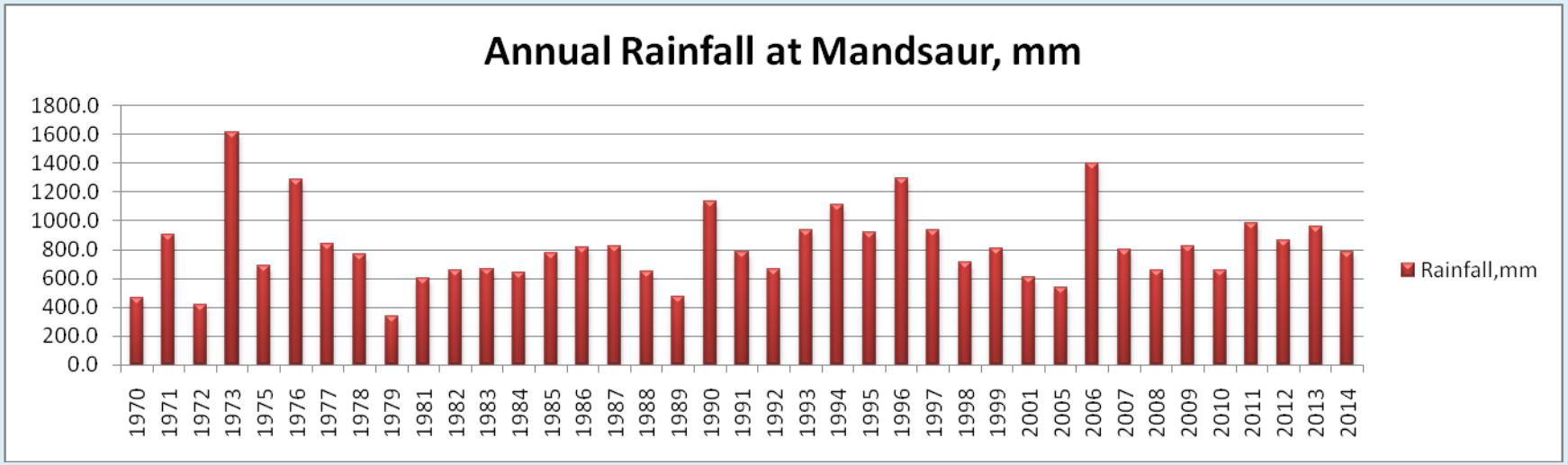
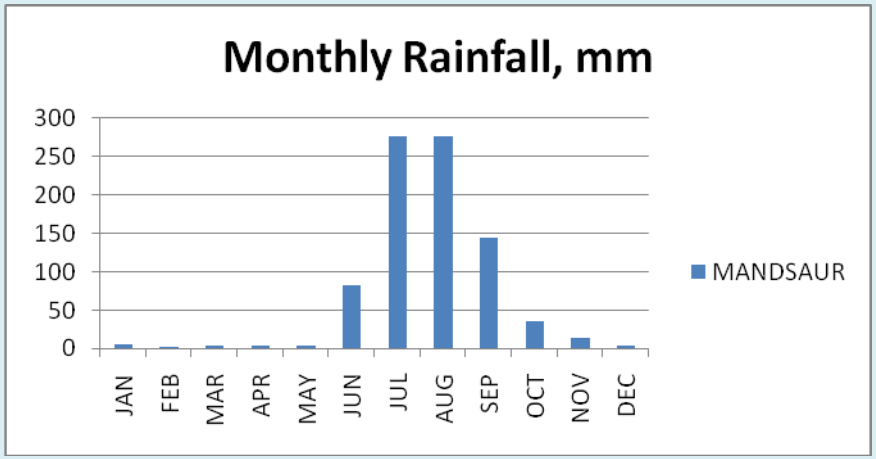


Fig. 57C Rainfall analysis at district Indore, Agro-Climatic Zone –IX, Malwa Plateau





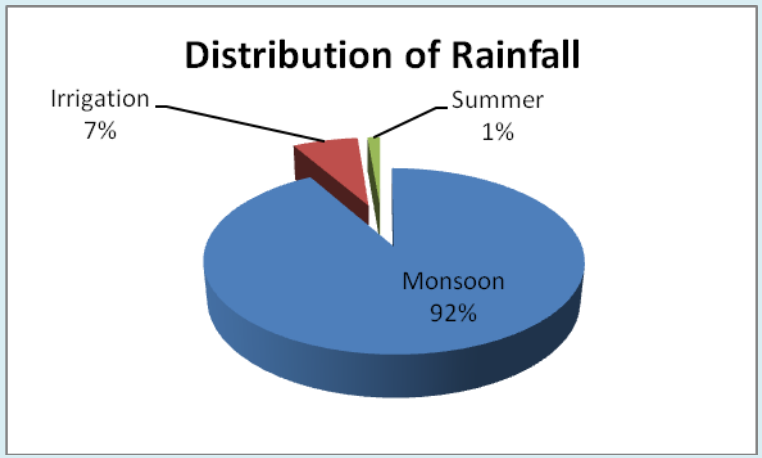
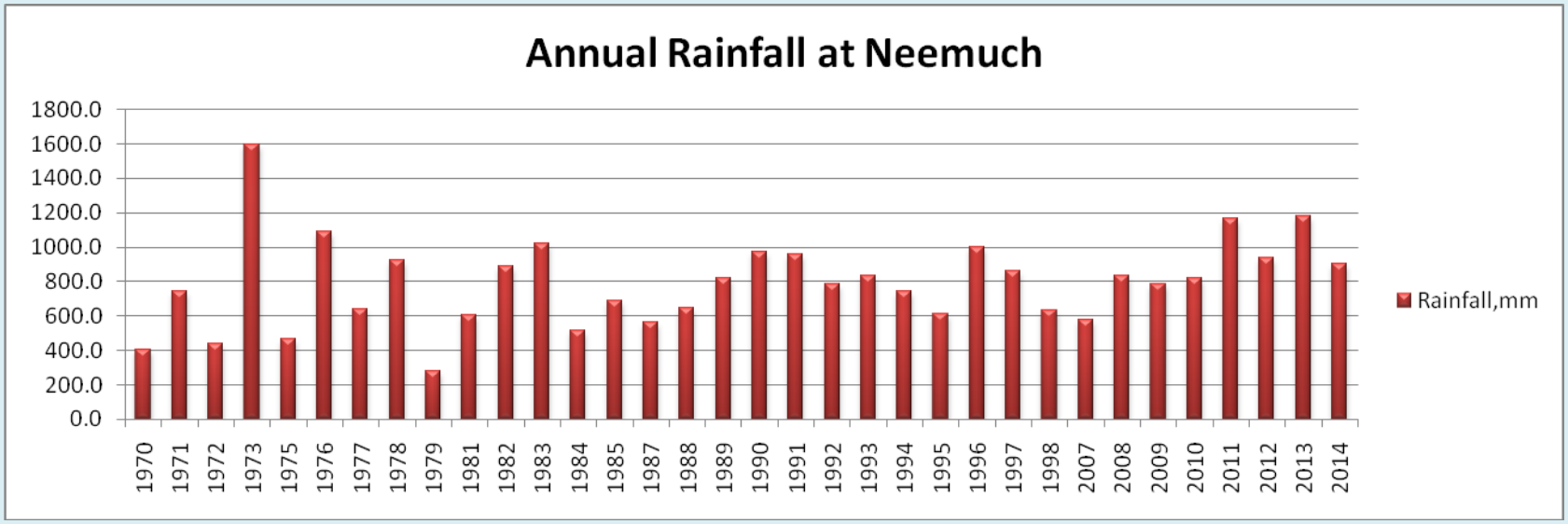
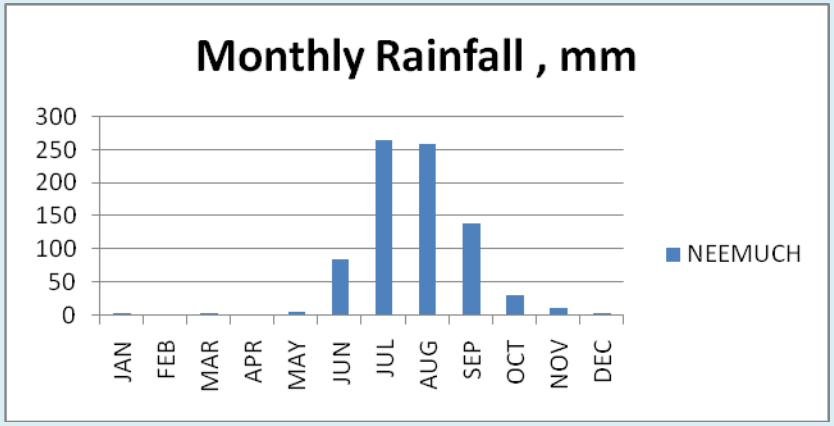


Fig. 57D Rainfall analysis at district Mandsaur, Agro-Climatic Zone –IX, Malwa Plateau





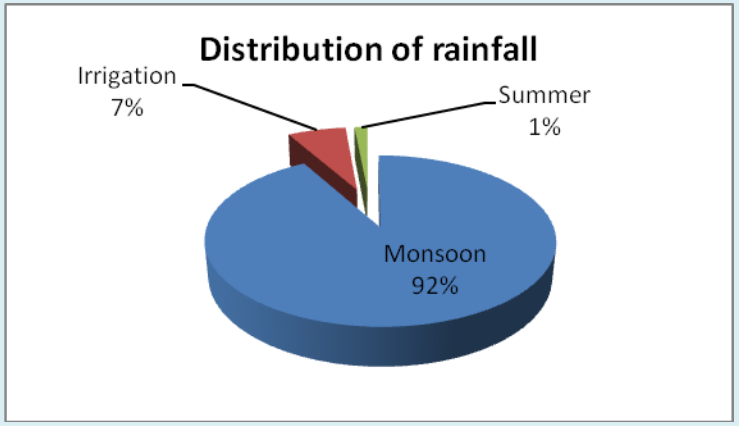
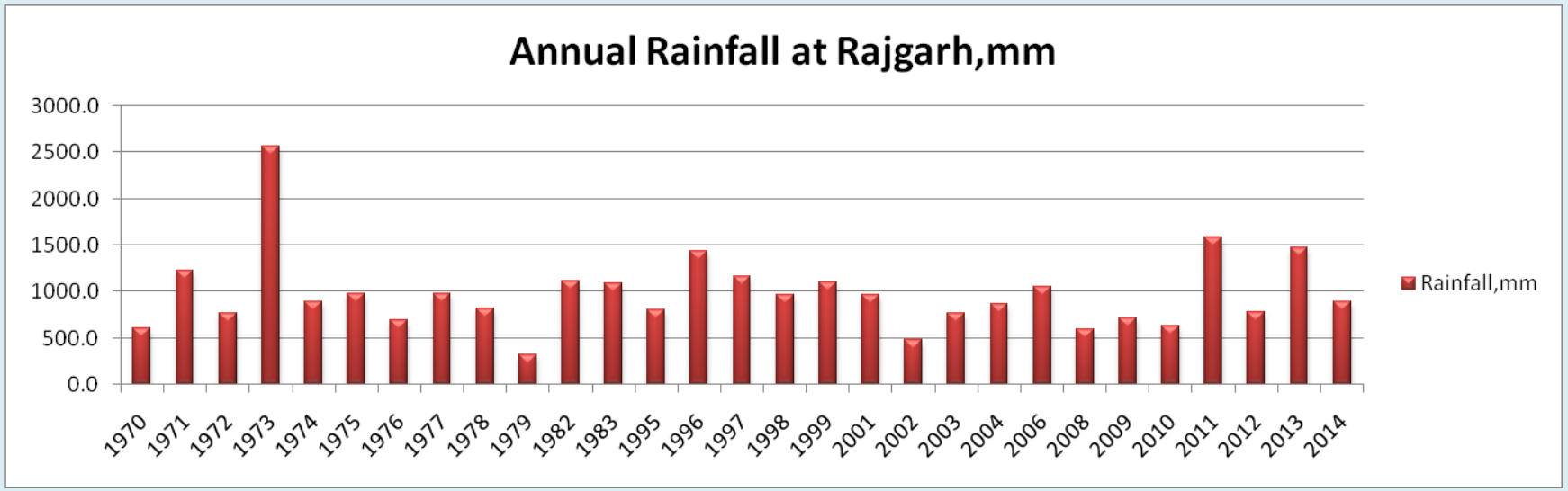
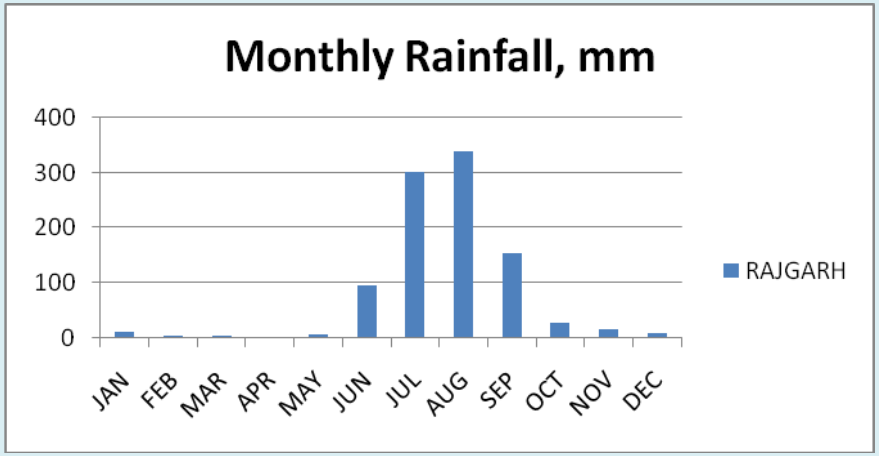


Fig. 57E Rainfall analysis at district Neemuch, Agro-Climatic Zone –IX, Malwa Plateau





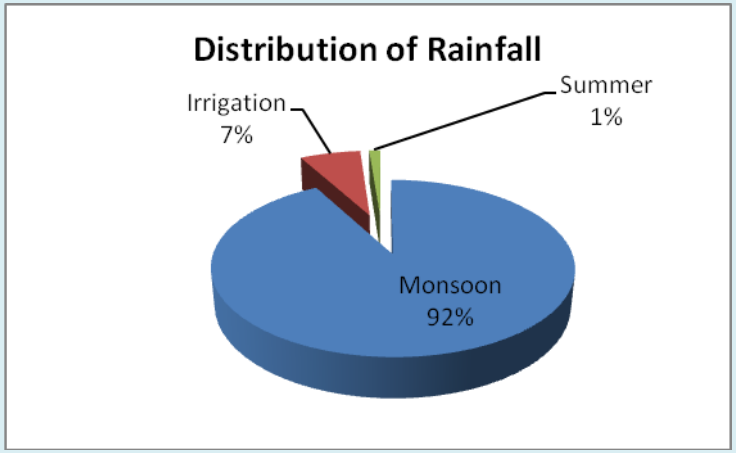
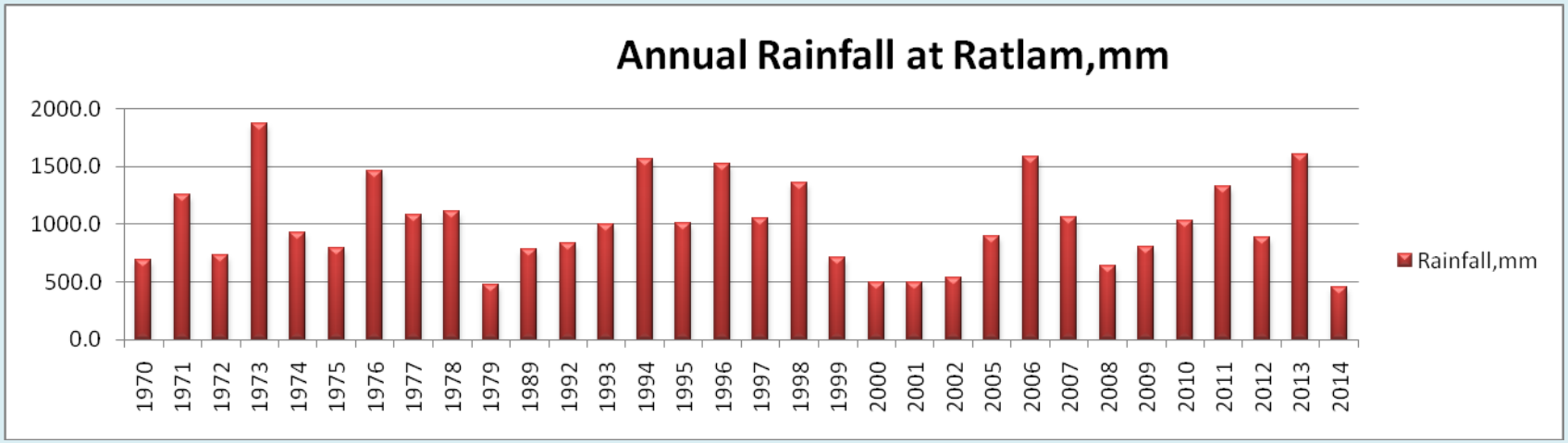
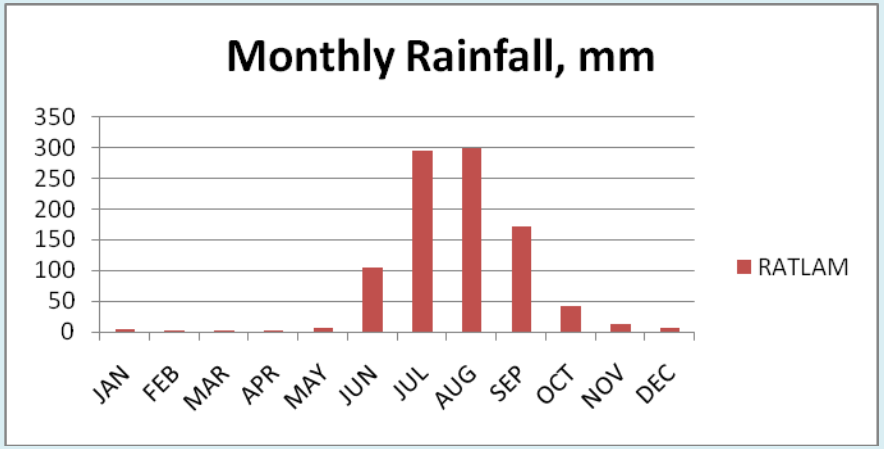


Fig. 57F Rainfall analysis at district Rajgarh, Agro-Climatic Zone –IX, Malwa Plateau





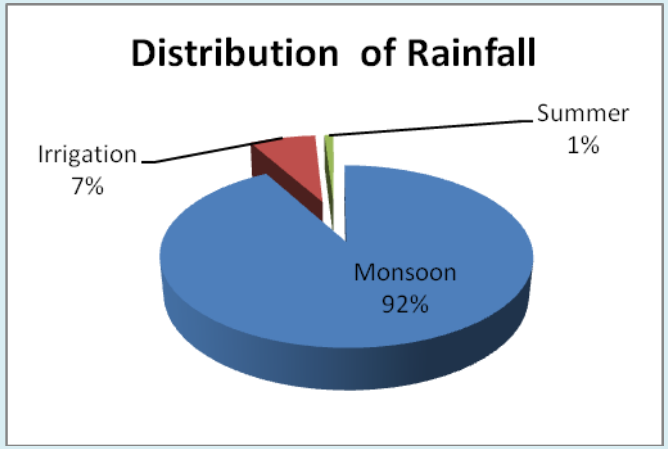
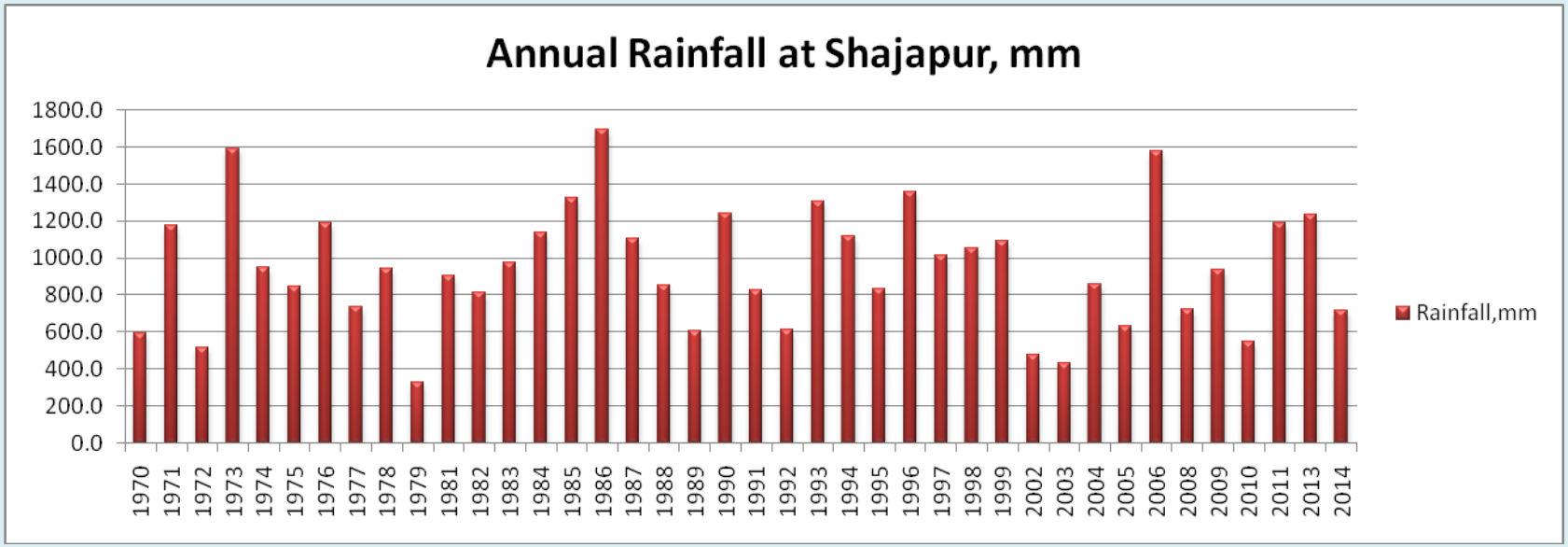
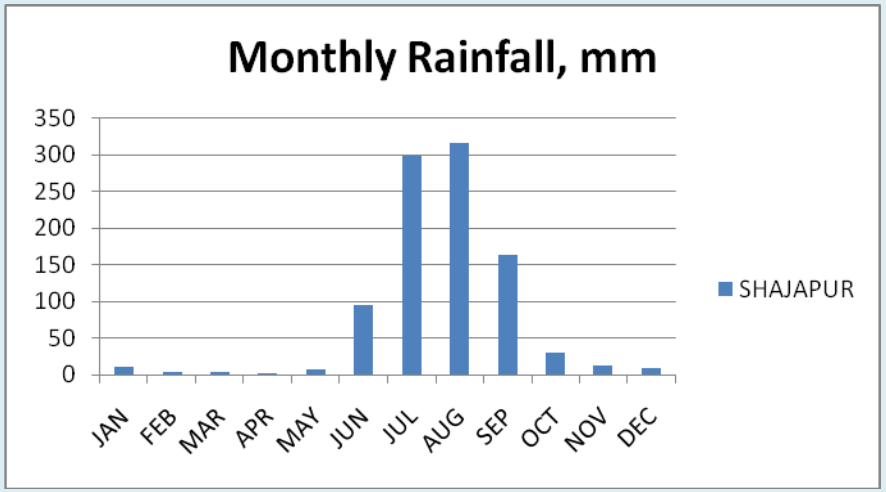


Fig. 57G Rainfall analysis at district Ratlam, Agro-Climatic Zone –IX, Malwa Plateau





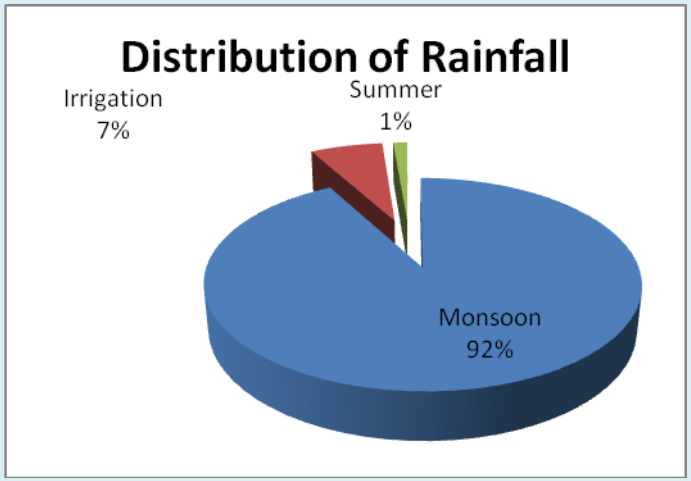
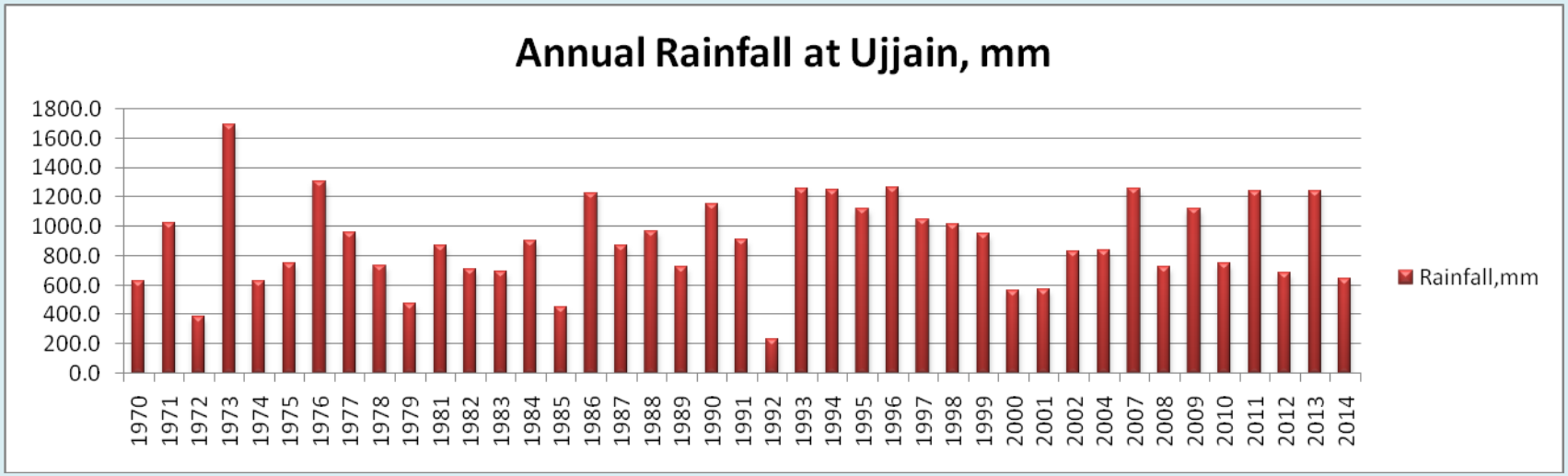
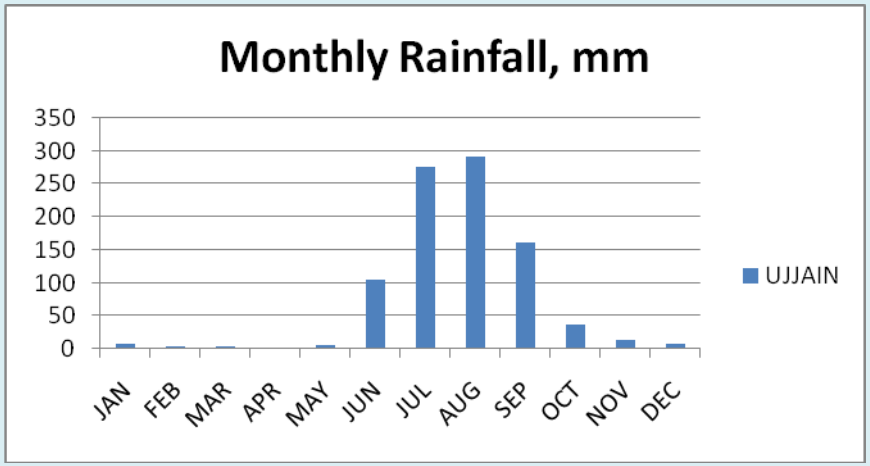


Fig. 57H Rainfall analysis at district Shajapur, Agro-Climatic Zone –IX, Malwa Plateau





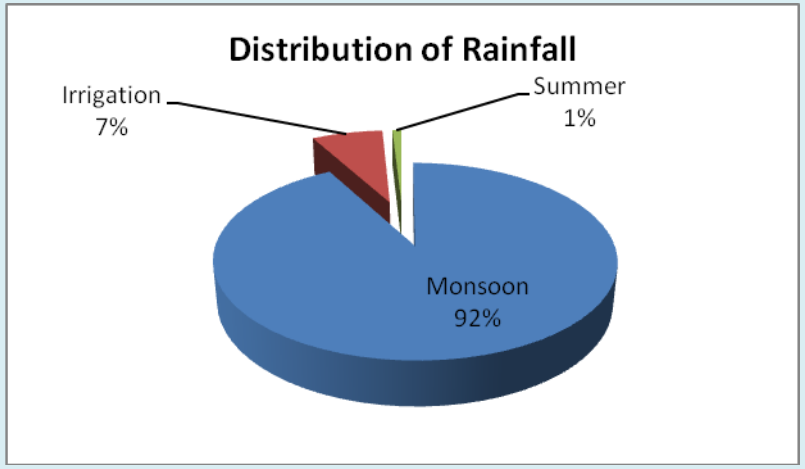


Fig. 57 I Rainfall analysis at district Ujjain, Agro-Climatic Zone –IX, Malwa Plateau

Table 34 illustrates water requirement towards human needs as well as for live stock. Live stock population comprises of cattle both cross breed and indigenous, buffalo, bovine, sheep, goat, horses and ponnies, mules, donkey, pigs, dogs, rabbits, fowls, ducks, turkey and other poultry. The indigenous cattles are about 8 times more than the cross breed cattles and Indore district has maximum percentage (84.7%) of cross breed cattle. All other districts are well behind as the nearer one is Ujjain which has 14.0% of their cattles as cross breed. This indicates that the zone has tremendous scope for breeding improvement programmes. Total bovine population of the zone is more than double the buffalo population (2039707). Rajgarh has maximum number of buffalo (25.0 %) and Neemuch has the minimum buffalo population (6.7%). Bovine is the main cattle class and out of available 4530374 and Rajgarh again stood first in this category with 22.0% zonal share. Indore comes last in this cattle group with 7.3% zonal share. The sheep is mostly populated in Mandsaur and Neemuch totaling 74.7% of the zone. Goat is evenly populated throughout the zone. Other common animals of the zone is Fowls (494190), dogs (32423) and pigs (15919). Mandsaur tops in Horse (927), camels (1280) and pigs (4267) category Fowls are mostly populated in Ratlam district (31.2%). The zone has only numeric numbers of animals like rabbits and mules. Total water needs comes out 46347 ha-m. Livestock water needs of Rajgarh is maximum (21.9%) followed by Ujjain (13.0%), Dewas (12.6%), Mandsaur (11.5%), Ratlam(10.7%), Nimuch(8.3%), Indore(7.6%), Shajapur (7.1%) and Agar Malwa (7.0%).

Water requirement of crops

The zone is a Cotton-Jowar zone has 18077 ha under Jowar and 28055 ha under cotton. Jowar is dominated in Rajgarh (49.4%) and is dominated in Ratlam (74.6%). Wheat and soybean is now mostly taken in the zone as wheat is being cultivated in 1235690 ha in which Ujjain (22.3%), Rajgarh (15.7%) and Dewas (15.5%) are the main contributors. Soybean covers an area of 2421168 ha in which Ujjain (19.2%), Dewas (14.5%) and Rajgarh (14.1%) are leading districts. Other major crops are gram (602221 ha), rapeseed and mustard (94061 ha) and maize (181019 ha). Apart from this other pulses (kharif) are also taken in 28171 ha. Dewas and Ujjain together contributes with 38.9% gram coverage. Rapeseed and mustard is mostly taken in Mandsaur (51.1%). Rajgarh and Ratlam together contributes in 46.5% of maize cultivation.

Table 34 : Live stock and Human water needs of ACZ IX

	Dewas	Indore	Mandsaur	Neemuch	Rajgarh	Ratlam	Shajapur	Ujjain
Cross breed Cattle	30259	81455	51231	21422	13223	30443	29690	33558
Water Req. (l/day)	4538850	12218250	7684650	3213300	1983450	4566450	4453500	5033700
Indigenous Cattle	314631	96129	245841	226366	478634	292175	306744	238866
Water Req. (l/day)	31463100	9612900	24584100	22636600	47863400	29217500	30674400	23886600
Buffalo	236555	155290	224443	138044	510774	172635	292145	309821
Water Req. (l/day)	35483250	23293500	33666450	20706600	76616100	25895250	43821750	46473150
Bovine	581445	332874	521515	385832	1002631	495253	628579	582245
Water Req. (l/day)	87216750	49931100	78227250	57874800	150394650	74287950	94286850	87336750
Sheep	668	629	10181	8930	857	3245	321	724
Water Req. (l/day)	6680	6290	101810	89300	8570	32450	3210	7240
Goat	165742	96272	182244	145131	188593	200927	199970	205774
Water Req. (l/day)	1657420	962720	1822440	1451310	1885930	2009270	1999700	2057740
Horse & Ponies	84	715	927	425	188	792	244	614
Water Req. (l/day)	2730	23237.5	30127.5	13812.5	6110	25740	7930	19955
Mules	25	776	13	0	18	502	2	49
Water Req. (l/day)	812.5	25220	422.5	0	585	16315	65	1592.5
Donkey	177	81	584	176	643	194	499	761
Water Req. (l/day)	5752.5	2632.5	18980	5720	20897.5	6305	16217.5	24732.5
Camels	1	0	1280	590	19	8	438	356
Water Req. (l/day)	115	0	147200	67850	2185	920	50370	40940
Pigs	740	4	4267	1258	2719	1384	3299	2248
Water Req. (l/day)	7400	40	42670	12580	27190	13840	32990	22480
Dogs	5361	4145	3937	1691	2278	7991	1379	5641
Water Req. (l/day)	26805	20725	19685	8455	11390	39955	6895	28205
Rabbits	11	115	46	18	36	60	21	62
Water Req. (l/day)	7.04	73.6	29.44	11.52	23.04	38.4	13.44	39.68

Elephants	6	74	0	0	0	1	0	18
Water Req. (l/day)	900	11100	0	0	0	150	0	2700
Fowls	86881	60670	31150	28720	15620	154046	51536	65567
Water Req. (l/day)	21720.25	15167.5	7787.5	7180	3905	38511.5	12884	16391.75
Ducks	14	308	129	98	30	295	111	44
Water Req. (l/day)	3.5	77	32.25	24.5	7.5	73.75	27.75	11
Turkeys	0	45	2	0	16	228	0	2
Water Req. (l/day)	0	11.25	0.5	0	4	57	0	0.5
Other Poultry	0	0	27	23	0	319	0	464
Water Req. (l/day)	0	0	6.75	5.75	0	79.75	0	116
TWR lpd	161854896	96123044	147631458	107046273	281040676	137511353	176881781	164952344
TWR ha m	5856	3508	5342	3872	10177	4969	6400	6020
Human Population	1563107	3272335	1339832	825958	1546541	1454483	1512353	1986864
TWR human, ha-m	7702	16124	6602	4070	7621	7167	7452	9790

Table 35 A : Water requirement of field crops in Malwa Plateau, ha m

Crops	Agar Malwa		Dewas		Indore		Mandsaur		Neemuch		Rajgarh		Ratlam		Shajapur		Ujjain	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Rice	2	1	113	79	5	4	0	0	38	28	364	271	1293	971	44	28	0	0
Jowar (Kharif)	2750	1274	2359	1053	181	84	180	84	494	231	8937	4142	42	20	2488	985	646	288
Jowar (Rabi)	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0
Bajra	5	2	0	0	0	0	26	10	9	4	12	5	0	0	0	0	0	0
Maize	15270	7762	9048	4430	4240	2148	27652	14197	23726	12181	41304	20995	42893	22094	10276	4463	6610	3236
Ragi		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wheat	40434	24907	192236	104602	115881	71553	113950	67686	53379	31707	194096	119563	123114	77463	126374	63667	276226	150304
Barley	286	168	5	3	0	0	321	182	1288	730	146	86	42	25	1	0	18	9
Other Cereals and Millets (Kharif)	0	0	0	0	0	0	0	0	0	0	0	0	42	21	0	0	0	0
Other Cereals and Millets (Rabi)	0	0	0	0	0	0	0	0	0	0	0	0	12	7	0	0	0	0
Gram	41916	23766	109463	54825	67221	38205	24566	13431	10252	5605	86798	49214	71233	41255	65673	30454	125099	62656
Arhar(Tur)	1834	1100	3234	1796	186	110	589	350	460	274	2066	1239	961	585	1687	843	1312	728
Other Pulses (Rabi)	7448	3962	151	71	488	260	4734	2429	828	425	11552	6146	2579	1401	7369	3206	1510	710
Other Pulses (Kharif)	2371	1111	147	65	1115	519	11748	5514	2923	1372	3856	1807	3305	1564	785	312	1921	847
Sugarcane	14	19	174	222	41	55	15	20	4	5	10	13	14	19	120	137	30	38
Groundnut	1077	564	276	139	116	60	1362	720	3865	2043	1458	763	423	224	577	258	199	100
Castor seed		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sesamum	671	337	275	130	1	0	374	188	646	325	1301	653	304	154	45	19	20	9
Rapeseed and Mustard	5205	2834	452	211	64	35	48016	25100	18241	9535	8348	4545	9865	5468	2605	1139	1265	589
Linseed	33	19	30	15	9	5	6012	3287	428	234	0	0	1998	1157	2	1	50	25
Soyabean	137322	53377	350963	131401	231222	89575	286396	112439	129870	50987	342419	133098	236408	93121	241902	80348	464666	173971
Niger seed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sunflower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Safflower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Oilseeds	230	128	0	0	0	0	1432	800	727	406	0	0	832	469	0	0	68	36
Cotton	0	0	6625	4752	38	29	403	310	64	49	0	0	20927	16461	0	0	0	0
Jute	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesta	0	0	27	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sanhemp	21	17	24	20	0	0	0	0	2	2	13	11	3	2	0	0	21	17
Other Fibres	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 35 B : Water requirement of fruits and vegetables crops in Malwa Plateau, ha m

Crops	Agar Malwa		Dewas		Indore		Mandsaur		Neemuch		Rajgarh		Ratlam		Shajapur		Ujjain	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Chillies	598	657	6	7	120	132	658	712	85	92	585	642	2756	3078	218	208	72	79
Ginger	2	2	55	64	11	13	0	0	0	0	0	0	107	133	1	1	1	1
Turmeric	1572	1910	5	6	0	0	0	0	6	7	0	0	10	12	0	0	6	7
Betel nut	14333	16288	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
Garlic	985	1586	6211	9804	4086	6564	11388	18121	9027	14364	2174	3500	13970	22799	3565	5000	12271	19369
Coriander	0	0	121	159	35	50	31346	44323	8009	11325	33574	48279	1321	1934	918	1100	984	1297
Other Condiments and Spices	1	1	9	11	31	39	13761	16867	4950	6067	1142	1421	10684	13522	614	663	1998	2474
Mango	10	16	38	60	43	69	0	0	5	8	68	109	43	70	38	53	46	73
Banana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Citrus Fruits	963	1246	163	207	30	39	3921	5016	634	811	567	734	558	732	553	624	165	209
Grapes	0	0	0	0	18	18	0	0		0		0	76	78	1	1	0	0
Papaya	18	30	54	87	6	10	13	21	3	5	8	13	14	23	7	10	21	34
Other Fruits	0	0	72	114	283	455	475	756	138	220	7	11	80	131	21	29	200	316
Potato	795	752	8560	7362	20124	19271	24	22	6	5	1057	999	193	187	6066	4814	7211	6201
Sweet Potato	66	44	0	0	3	2	70	47	5	3	143	96	27	18	0	0	1	1
Onion	2015	3435	8624	14413	2623	4462	1292	2177	1239	2087	2682	4572	2156	3726	8184	12153	4859	8121
Other Vegetables (Kharif)	54	36	602	379	2560	1703	415	278	118	79	357	239	2407	1627	317	180	489	308
Other Vegetables (Rabi)	255	193	3267	2182	2105	1595	456	332	194	141	736	556	945	730	515	318	6572	4389
Opium	0	0	0	0	0	0	2168	2107	1308	1271	0	0	139	143	0	0	0	0
Tobacco	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	18	10
Other Plantation Crops	0	0	0	0	45	81	9654	17169	20454	36375	5	9	594	1083	0	0	119	210
Fodder Crops	19177	13079	24839	15938	13129	8894	22518	15378	17629	12039	38163	26027	24731	17025	20529	11855	22974	14742
Other Non Food Crops	9	12	191	227	572	740	52	66	25	32	4	5	322	424	13	14	335	397

Table 35 A-B. Based on growing period, crop coefficient values, the water requirement of all the crops were worked out and presented in Table 35A. Total yearly water requirement of the crops of the zone is 1952958 ha-m. The major user of water, in terms of crop water requirement, is Ujjain district (16.4%) followed by Rajgarh (15.7%), Mandsaur(13.4%), Dewas (12.8%), Ratlam (11.6%), Indore (9.2%), Shajapur (7.9%), Nimuch (7.2%)and Agar (5.7%.). Figure 58-60 depicts crop water requirement of major crops in the districts of the zone.

Table 35B shows vegetable and fruits crops acreage in different districts of the zone. Coriander (76308 ha), Garlic (63677 ha), Potato (44036 ha) and Onion (33674 ha) are the major vegetables of the zone. Mandsaur and Rajgarh together dominate in Coriander (73.6%). Indore and Neemuch together dominates in Potato (45.7%), Dewas and Shajapur dominates in Onion (49.9%) and Ujjain is ahead in cultivation of other vegetables in rabi i.e. 43.7% of zonal total of 15045 ha. Other Condiments and spices are taken in 33190 ha in the zone and Mandsaur and Ratlam are the toppers in this group with 73.6% share. Opium is the special crop of this zone but confined mostly in Mandsaur (2168 ha) and Neemuch (1308 ha). Fodder crops are also taken in big way in this zone in total area of 203687 ha with maximum (18.7%) in Rajgarh and Minimum area in Indore (6.4%).

Water budget

The agroclimatic zone IX (ACZ IX)- Malwa Plateau receives total quantum of water towards rainfall as 3963953 ha-m. Maximum (18.8 %) of it receives in district Dewas followed by Ujjain (13.7%), Rajgarh (13.0 %), Ratlam (%), Mandsaur (11.0%), Indore (9.3%), Neemuch (8.3%), Shajapur (8.1%) and Agar Malwa (6.4%). National Commission on Agriculture has laid down norms for water budgeting of an area and as per its estimate the losses of water as evaporation, surface water flow and ground water flow out of the area is calculated in present estimation. Similarly, addition of water into the area as runoff generated from the zone, addition of soil moisture and to the ground water is also computed. The water budget so generated for ACZ IX is presented in Table 36. The immediate evaporation loss that occurs during the rainfall is taken as 17.5% of total rainfall and it is 693692 ha-m for the zone. 28.7% rainfall converts into surface flow and it is 1137655 ha m. It is considered that 10.549%

(188999 ha m) of surface flow goes out of the zone. Ground water also adds to the surface flow and it is taken as 23.739% of surface flow.

Table 36 : Water budgeting of Malwa plateau

S.N	Particulars	Agar Malwa	Dewas	Indore	Mandsor	Neemuch	Rajgarh	Ratlam	Shajapur	Ujjain	Zone Total
1	Normal rainfall, ha-m	252680	746892	368118	437361	322321	516459	456555	320779	542788	3963953
2	Immediate evaporation (17.5%)	44219	130706	64421	76538	56406	90380	79897	56136	94988	693692
3	Surface flow (28.7%)	72519	214358	105650	125523	92506	148224	131031	92064	155780	1137655
4	From outside state(10.549% of total surface flow)	12048	35611	17552	20853	15368	24624	21768	15295	25880	188999
5	To GW from flood flows (-4.851% of total surface flow)	-5540	-16376	-8071	-9589	-7067	-11324	-10010	-7033	-11901	-86912
6	From GW to surface flow(23.739% of total surface flow)	27111	80138	39497	46927	34584	55414	48986	34418	58239	425314
7	From irrigated area to surface flow(7.067% of total surface flow)	8071	23857	11758	13970	10295	16496	14583	10246	17337	126614
8	Total surface flow(45.198% of total ppt)	114206	337580	166382	197678	145683	233429	206354	144986	245329	1791627
9	Evaporation losses from reservoirs and tanks (7.916% of total surface flow)	9041	26723	13171	15648	11532	18478	16335	11477	19420	141825
10	Flow into seas and outside state (43.445% of total surface flow)	49617	146662	72285	85881	63292	101413	89650	62989	106583	778373
11	Utilizable surface flow (48.639% of total surface flow)	55549	164196	80927	96149	70859	113538	100368	70520	119326	871430
12	Water available for ground water storage (12.5%)	31585	93362	46015	54670	40290	64557	57069	40097	67849	495494
13	From streams and flood flows to GW(4.851% of total surface flow)	5540	16376	8071	9589	7067	11324	10010	7033	11901	86912
14	From irrigation to GW addition (S.N.15-(12+13))	17181	50785	25030	29738	21916	35116	31043	21811	36907	269527
15	Total GW (21.492% of total ppt)	54306	160522	79116	93998	69273	110997	98123	68942	116656	851933

16	Evaporation and rise of water table (18.451% of total GW)	10020	29618	14598	17344	12782	20480	18105	12720	21524	157190
17	Regeneration into streams(49.924% of total GW)	27112	80139	39498	46927	34584	55414	48987	34419	58239	425319
18	GW available utilization(31.625% of total GW)	17174	50765	25020	29727	21908	35103	31031	21803	36892	269424
19	Total utilizable surface + GW (S.N. 11+18)	72723	214961	105947	125876	92766	148641	131400	92322	156218	1140853
20	Soil moisture storage (41.3% of normal rainfall)	104357	308466	152033	180630	133119	213298	188557	132482	224171	1637113
21	From irrigated area to soil moisture(7.067% of total surface flow)	8071	23857	11758	13970	10295	16496	14583	10246	17337	126614
22	Total soil moisture storage (44.495% of total ppt)	112430	332330	163794	194604	143417	229798	203144	142731	241514	1763761
23	Evaporation losses from soil moisture (31.504% of total soil moisture storage)	35420	104697	51602	61308	45182	72396	63999	44966	76086	555655
24	Evap. losses from forest and other veg. (30.826% of total soil moisture)	34658	102444	50491	59989	44210	70838	62621	43998	74449	543697
25	Soil moisture available for ET from crops (37.673 % of total soil moisture)	42356	125199	61706	73313	54029	86572	76530	53771	90985	664462
26	Water requirement of crops	110730	250437	179247	261494	140625	306608	227438	155593	320784	1952956
27	Water requirement of animal husbandry	3290	5856	3508	5342	3872	10177	4969	3310	6021	46345
28	Domestic water requirement	3727	7702	16124	6602	4070	7621	7167	3726	9789	66528
29	Industrial Water requirement @ 6 % of available fresh water	15060	42821	20313	35820	23734	39616	26260	22265	37365	263254
30	Water available for utilization (S.N. 19+25)	115079	340159	167653	199189	146796	235212	207930	146093	247204	1805315
31	Water required for different sectors (26+27+28+29)	132807	306816	219192	309258	172301	364022	265834	184894	373959	2329083
32	Surplus or deficit of water in the district (30-31)	-17728	33343	-51539	-110069	-25505	-128810	-57904	-38801	-126755	-523768

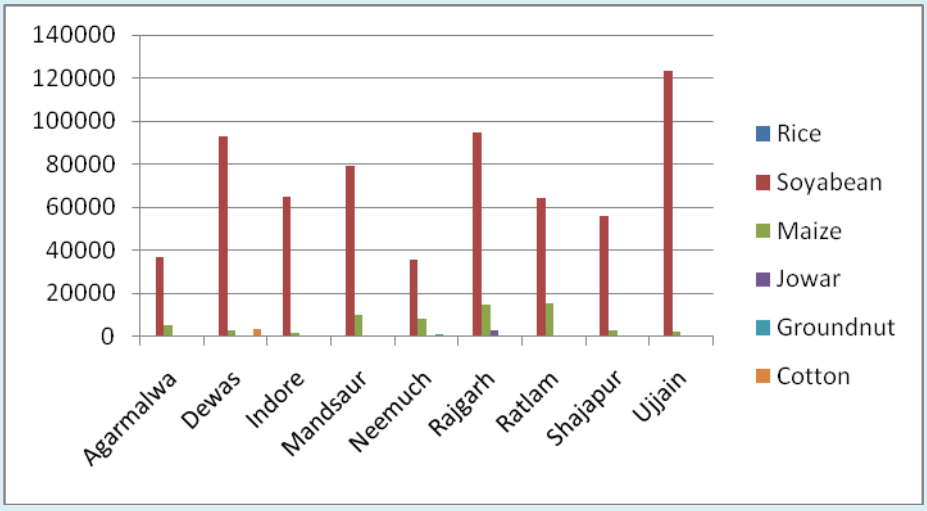


Fig. 58 Crop water requirement of major kharif crops of ACZ IX -Malwa Plateau in ha m

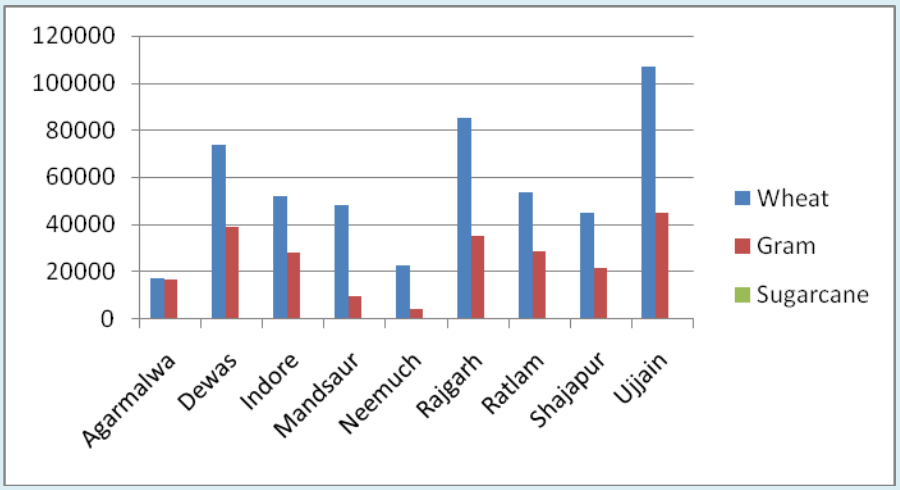


Fig. 59 Crop water requirement of major rabi crops of ACZ IX -Malwa Plateau in ha m

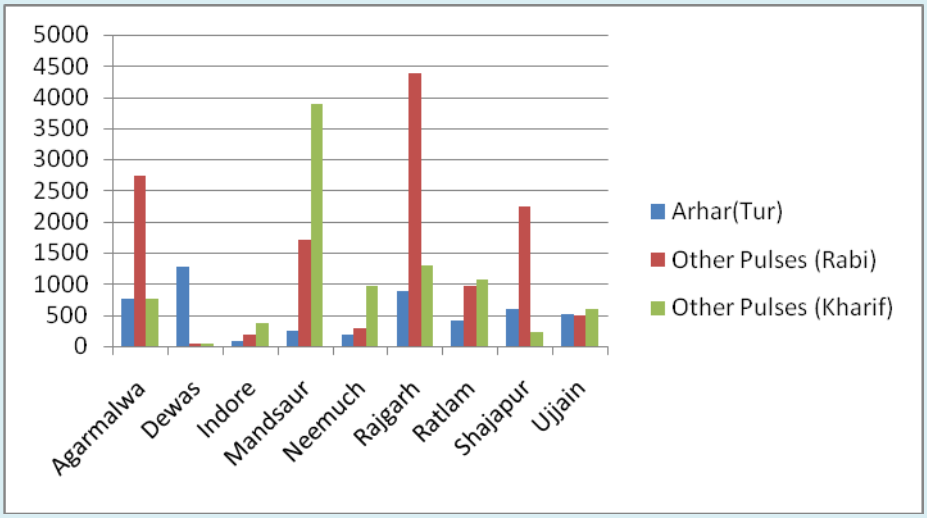


Fig. 60 Crop water requirement of pulse crops of ACZ IX -Malwa Plateau in ha m

Thus, surface flow arrives to be 1791627 ha-m which is 45.198% of total precipitation.

Evaporation takes place from open water body, soil surface, forest and vegetation and also from rise of water table, and respectively it is taken as 7.916% (141825 ha-m) of total surface flow, 31.504% (555655 ha-m) of total soil moisture storage, 30.826% (543697 ha-m) of total soil moisture and 18.5451% (157190 ha-m) of total ground water. Part of rainfall as recharge enriches ground water and it is 12.5 % (495494 ha-m). There is an addition to the ground water from streams and flood flows which is - 4.851 % (- 86912 ha-m) of total surface flow. The total utilizable surface and ground water for the ACZ IX computed as 1140853 ha-m.

The soil moisture increases due to rainfall as well as from irrigation. 41.3% of rainfall and 7.067% of total surface flow is considered as soil moisture storage. Total zonal soil moisture storage is 1763761 ha-m and out of this 664462 ha-m is available as ET for the crops. Each and every district of the ACZ IX zone contributes in same proportion in zonal water budgeting as the quantum of rainfall of each district contributes in zonal rainfall quantum owing to rainfall based water distribution.

Utilization of water takes place in four major categories. These are, domestic and animal water needs, crop water requirement and requirement of water for industrial and recreation. A water need of different sectors in districts of ACZ IX is presented in Fig. 61. Total crop water requirement of the zone is 1952956 ha-m and out of which Ujjain and Rajgarh together needs water towards crops as 32.1% of zonal total. The least crop water demand comes from Agar district (5.7%). In comparison to the crop water demand the water demand towards domestic and animal husbandry is very low as it is respectively 66528 ha-m and 46345 ha-m. Owing to higher population in Indore the domestic demand is about 24.2% of the zonal demand. Shajapur registers the least domestic water demand i.e. only 5.6% of zonal total. Rajgarh district has more animal husbandry and demand for 21.9% of the zonal water needs of it. The industrial demand is computed as 6% of available water thus total zonal demand comes out as 263254 ha m.

Total water needs and supply of different districts of ACZ IX is presented in Fig. 62. The excess/deficit of water is also shown in the figure. The water available for utilization at zonal level is 1805315 ha-m. The maximum share (18.8%) is available at Dewas district followed by Ujjain (13.7%), Rajgarh (13.0%), Ratlam (11.5%), Mandsaur (11.4%), Indore (9.3%), Neemuch (8.1%), Shajapur (8.1%) and Agar

Malwa (6.3%). The total zonal water demand is 2364968 ha m which gives a deficit of 559653 ha m at zonal level. In fact all district except Dewas has deficient water for their requirement. Rajgarh has the most deficient water (- 37%) followed by Mandsaur (- 34%), Shajapur (-32%), Ujjain (-31%), Indore (- 26), Neemuch (-22%), Ratlam (-21%) and Agar Malwa (-21%). An abstract in pictorial form is provided in Fig 63.

Taking net sown area of these district, as per Directorate of Extension and Farmers Welfare, 179833ha, 399376 ha, 251353 ha, 357181 ha, 183248 ha, 439102 ha, 337513 ha, 279500 ha and 499661 ha, the per hectare water excess/deficit due to this surplus water comes out to be -18 cm, 13 cm, -23 cm, -29 cm, -23 cm,-32 cm, -16 cm, -24 cm and -23 cm. It means, the future plans to enhance crop production or alternate cropping may be based on this much depth of water.

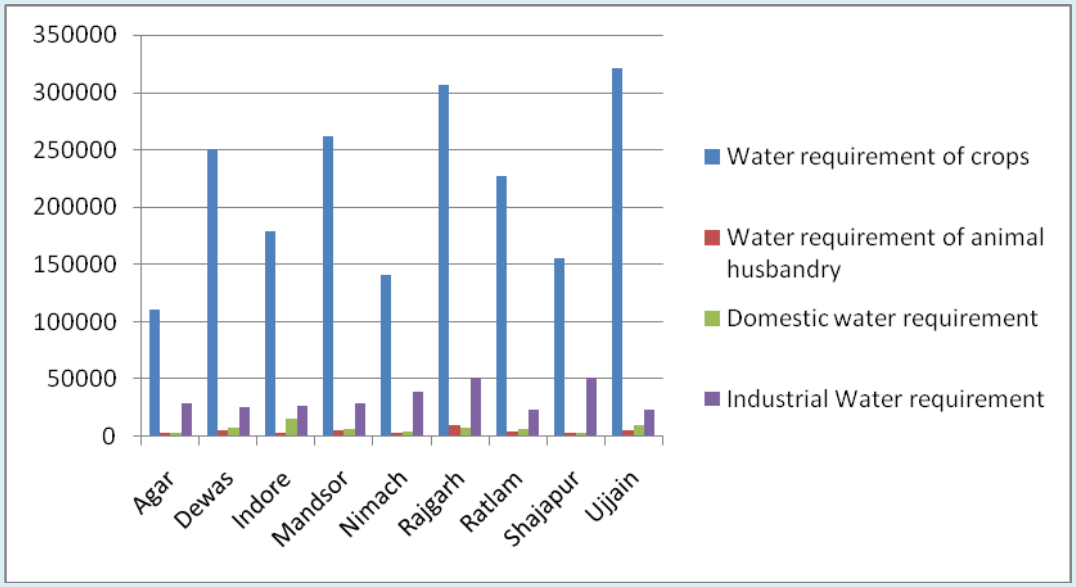


Fig. 61 Water needs of different sectors in districts of ACZ IX - Malwa Plateau (ha-m)

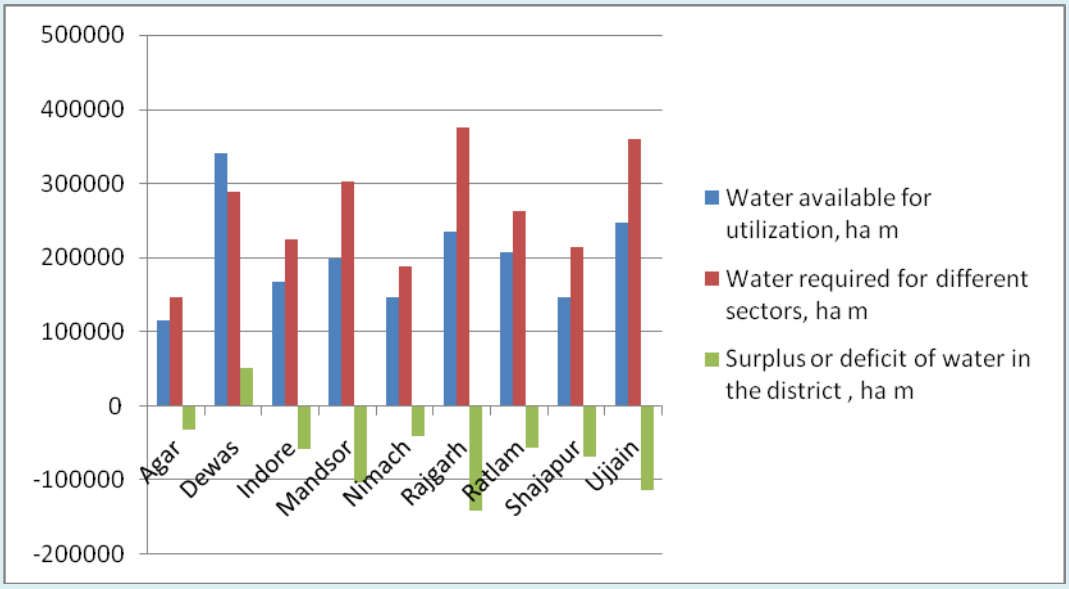


Fig. 62 Total Water needs and supply of different districts of ACZ IX - Malwa Plateau (ha-m)

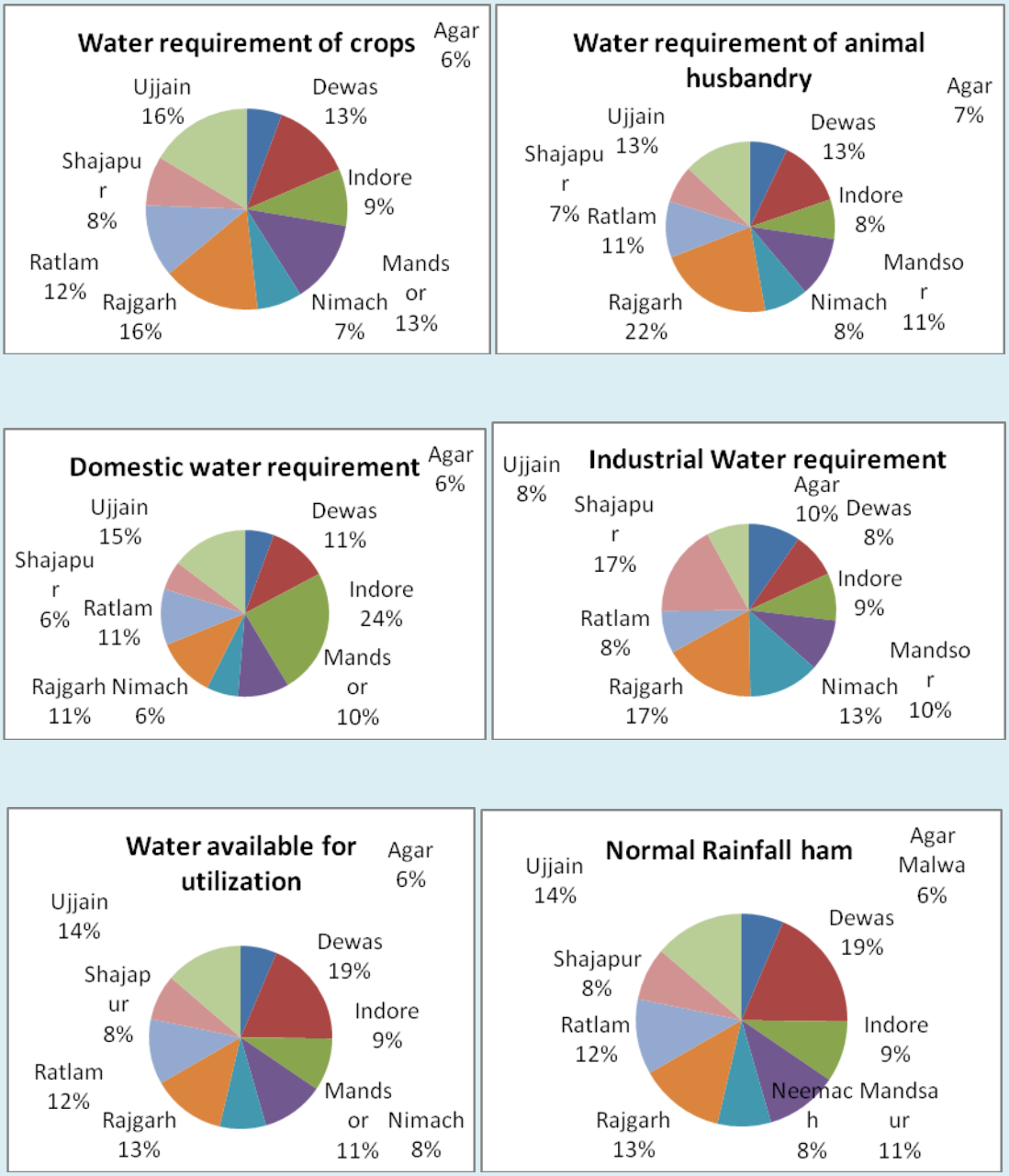


Fig. 63 Abstract of water of different districts of ACZ IX - Malwa Plateau (ha-m)

Agroclimatic Zone X - Nimar Plains

The Agroclimatic zone X – Nimar Plains covers nine districts namely Barwani, Burhanpur, Dhar, Khandwa (East Nimar), Harda and Khargone (West Nimar). It comes under Cotton- Jowar zone having medium black (medium) soils. The zone has total geographical area of 3616980 ha, out of which forest area is 32.1 % mostly in Dhar, Khargone and Khandwa totaling 66.7 %. Net area sown is 47.7% in which Dhar and Khargone has 52.4 % area. Out of total Net Sown area of 1724097 ha, the fallow land including current fallow is 2.1 %. District wise land utilization is presented in Table 37.

Rainfall analysis

Annual rainfall ranges from 800 to 1200 mm. On an average 92 % of this rainfall occurs during monsoon i.e. June to September, 7% in winter i.e. late December and 1% in summer. But in Burhanpur the monsoon rainfall, winter rainfall and summer rainfall is 88%, 9% and 3% respectively. Maximum rainfall occurs in the month of August except in Barwani and Dhar. In these two districts maximum rainfall occurs in July which is slightly higher than rainfall that occurs in August. The patterns of annual rainfall occurred in different districts of Agroclimatic zone X for years 1970 to 2014 are presented through Figures 64 A-F. Mean annual rainfall of these districts are 750.0 mm, 978.9 mm, 833.0 mm, 1374.5 mm ,777.6 mm and 835.0 mm respectively for Barwani, Burhanpur, Dhar, Khandwa, Harda and Khargone. The record also shows maximum ever rainfall of 2590 mm (1989) was occurred in Burhanpur. Rainfall of just less than 2000 mm was also occurred in Barwani, Harda and Khandwa in the year 2013. Except in these extreme years the annual rainfall rarely exceeds more than 1500 mm respectively for these districts, the annual rainfall exceeded the normal annual rainfall by 44.2%, 29.4%, 58.8%, 23.2%, 41.4% and 41.4% times.

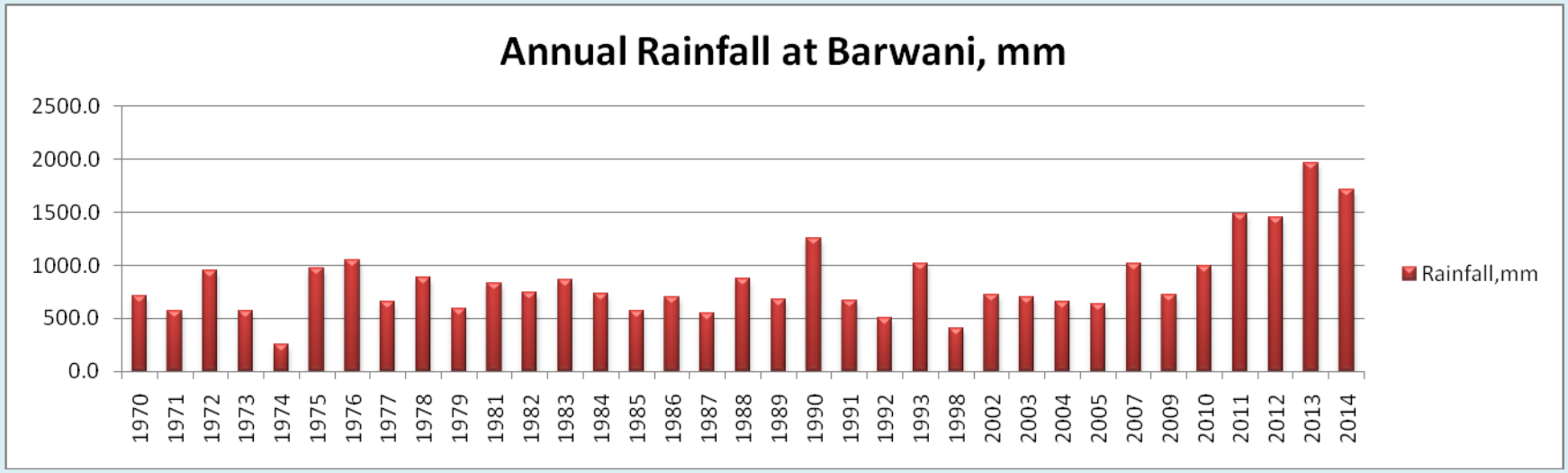
Domestic and livestock water needs

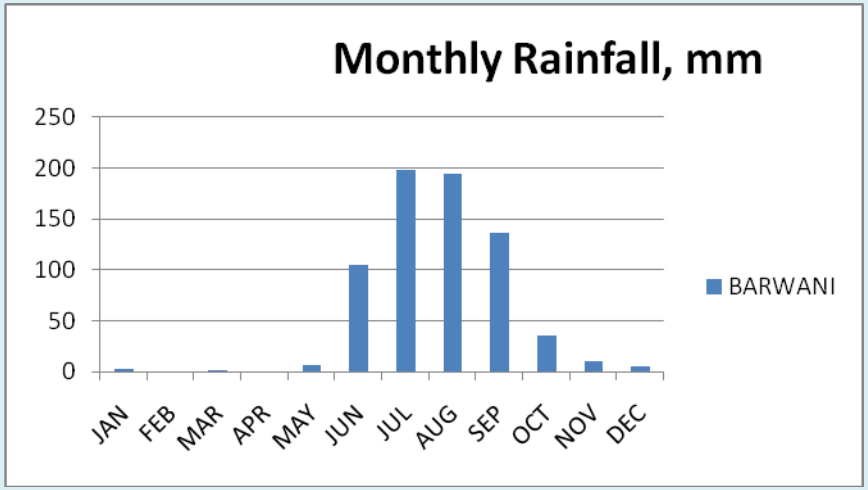
Total population of the zone is 8079482 as per Census 2011. Total human water needs of the zone is 39812 ha-m where the Dhar and Khargone together consume 50.2% of zonal requirement followed by Barwani (17.1%), Khandwa (16.2%), Burhanpur (9.4%) and Harda (7.1%) districts. Table 38 illustrates water requirement towards human needs as well as for live stock. Live stock population comprises of cattle both cross breed and indigenous,

Table 37 -Total Area and Classification of Area In Each District of Nimar Plains MADHYAPRADESH State for the year ending 2013- 14															
DISTRICT NAME	Reporting Area For Land Utilization Statics	Forests	Area Under Non Agricultural Uses	Not Available For Cultivation			Other Uncultivated Land Excluding Fallow Land			Fallow Land		Total	Net Area Sown	Total Cropped Area	Area Sown more than once
				Barren and Unculturable Land	Total	Permanent Pastures and Other Grazing Lands	Land Under Misc Tree crops and Groves not Included in Net Area	Culturable Waste Land	Total	Fallow Lands Other than Current Fallows	Current Fallows				
(1)	(2)	(3)	(4)	(5)	6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
BADWANI	529846	183067	28418	73134	101552	4764	0	6731	11495	2722	1362	4084	229648	289122	59474
BURHANPUR	342741	201919	15393	6363	21756	12510	110	5300	12510	1822	718	2540	104016	124672	20656
DHAR	819541	119740	58953	75743	134696	46877	32	12958	59867	2198	1142	3340	501898	818257	316359
KHANDWA	775616	305323	93591	8286	101877	49081	37	19290	49118	9154	6310	15464	303834	451472	147638
HARDA	330579	103439	22590	3422	26012	9203	78	8029	17310	1234	187	1421	182397	361132	178735
KHARGONE	818657	246872	47368	36155	83523	56772	18	19290	76080	7648	2230	9878	402304	547009	144705
Total	**3616980**	**1160360**	**266313**	**203103**	**469416**	**179207**	**165**	**71508**	**226380**	**24778**	**11949**	**36727**	**1724097**	**2591664**	**867567**

Table 38 : Live stock and Human water needs of ACZ X							
	Barwani	Burhanpur	Dhar	Khandwa	Harda	Khargone	Zone Total
Cross breed Cattle	599	2125	58107	1510	2469	1598	66408
Water Req. (l/day)	89850	318750	8716050	226500	370350	239700	9961200
Indigenous Cattle	399640	129372	565306	344854	139240	524152	2102564
Water Req. (l/day)	39964000	12937200	56530600	34485400	13924000	52415200	210256400
Buffalo	110663	36211	200419	121184	72850	203285	744612
Water Req. (l/day)	16599450	5431650	30062850	18177600	10927500	30492750	111691800
Bovine	510902	167708	823832	467548	214559	729035	2913584
Water Req. (l/day)	76635300	25156200	123574800	70132200	32183850	109355250	437037600
Sheep	2661	49251	2165	169	1416	1318	56980
Water Req. (l/day)	26610	492510	21650	1690	14160	13180	569800
Goat	306715	77342	435624	130576	45989	287754	1284000
Water Req. (l/day)	3067150	773420	4356240	1305760	459890	2877540	12840000
Horse & Ponies	55	1755	2040	672	45	290	4857
Water Req. (l/day)	1787.5	57037.5	66300	21840	1462.5	9425	157852.5
Mules	0	0	2050	837	2	0	2889
Water Req. (l/day)	0	0	66625	27202.5	65	0	93892.5
Donkey	715	506	386	83	8	385	2083
Water Req. (l/day)	23237.5	16445	12545	2697.5	260	12512.5	67697.5
Camels	0	0	3	0	0	9	12
Water Req. (l/day)	0	0	345	0	0	1035	1380
Pigs	796	531	530	1137	208	1475	4677
Water Req. (l/day)	7960	5310	5300	11370	2080	14750	46770
Dogs	2989	3840	8314	4149	8324	2472	30088
Water Req. (l/day)	14945	19200	41570	20745	41620	12360	150440
Rabbits	26	37	20	3	40	137	263
Water Req. (l/day)	16.64	23.68	12.8	1.92	25.6	87.68	168.32
Elephants	0	8	10	0	0	2	20
Water Req. (l/day)	0	1200	1500	0	0	300	3000
Fowls	701034	104809	636995	76440	27705	291314	1838297
Water Req.	175258.5	26202.25	159248.75	19110	6926.25	72828.5	459574.25

(l/day)							
Ducks	873	18	2877	1	12	1198	4979
Water Req. (l/day)	218.25	4.5	719.25	0.25	3	299.5	1244.75
Turkeys	450	0	639	0	0	0	1089
Water Req. (l/day)	112.5	0	159.75	0	0	0	272.25
Other Poultry	30	0	1	0	0	253	284
Water Req. (l/day)	7.5	0	0.25	0	0	63.25	71
TWR lpd	138644051	45808666	226355834	125581280	58445059	197561958	792396849
TWR ha m	4986	1651	8162	4542	2114	7136	28591
Human Population	1385659	756993	2184672	1309443	570302	1872413	8079482
TWR human, ha-m	6828	3730	10765	6452	2810	9226	39812





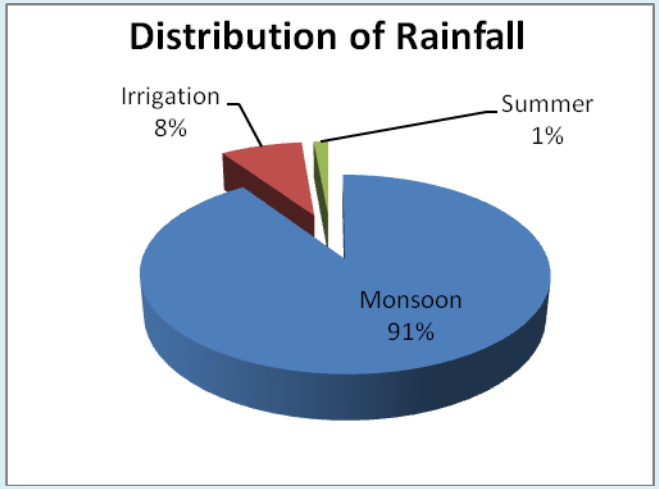
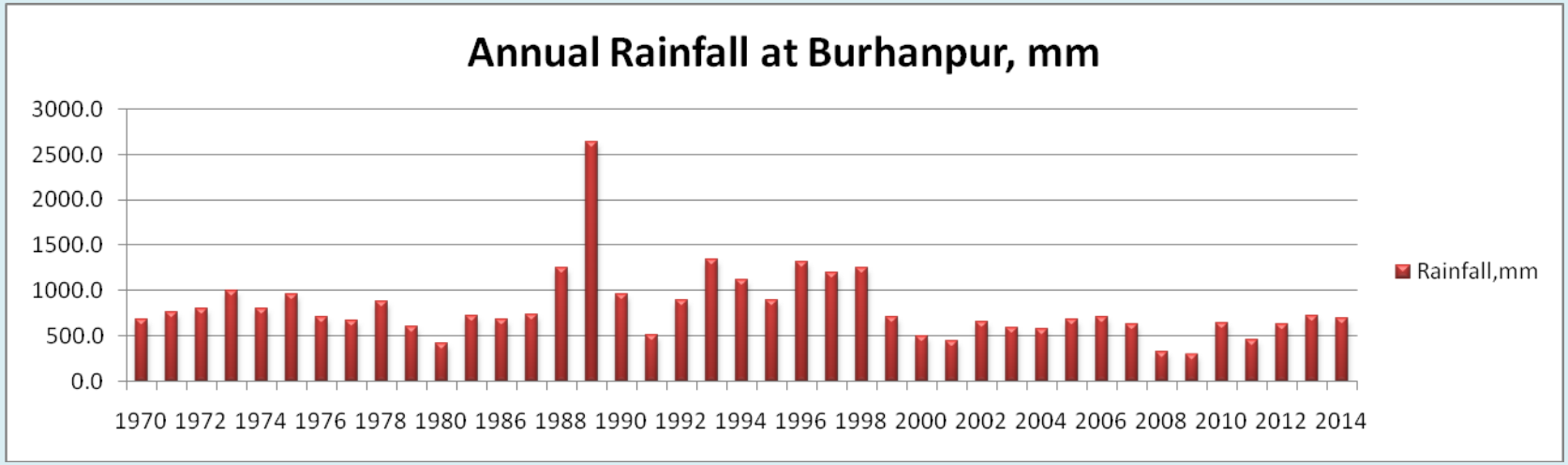
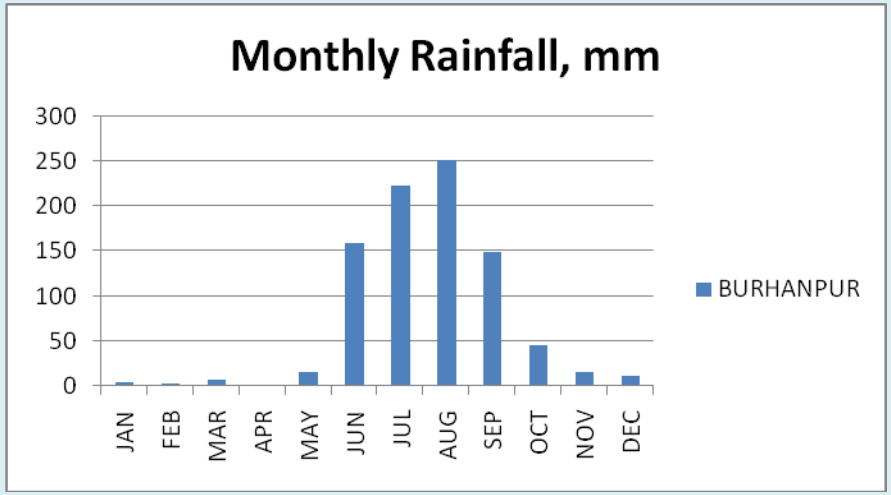


Fig. 64A Rainfall analysis at district Barwani, Agro-Climatic Zone –X, Nimar Plains





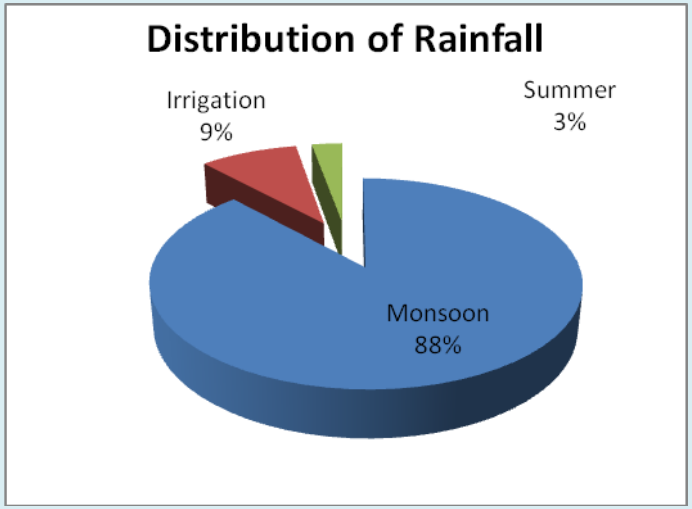
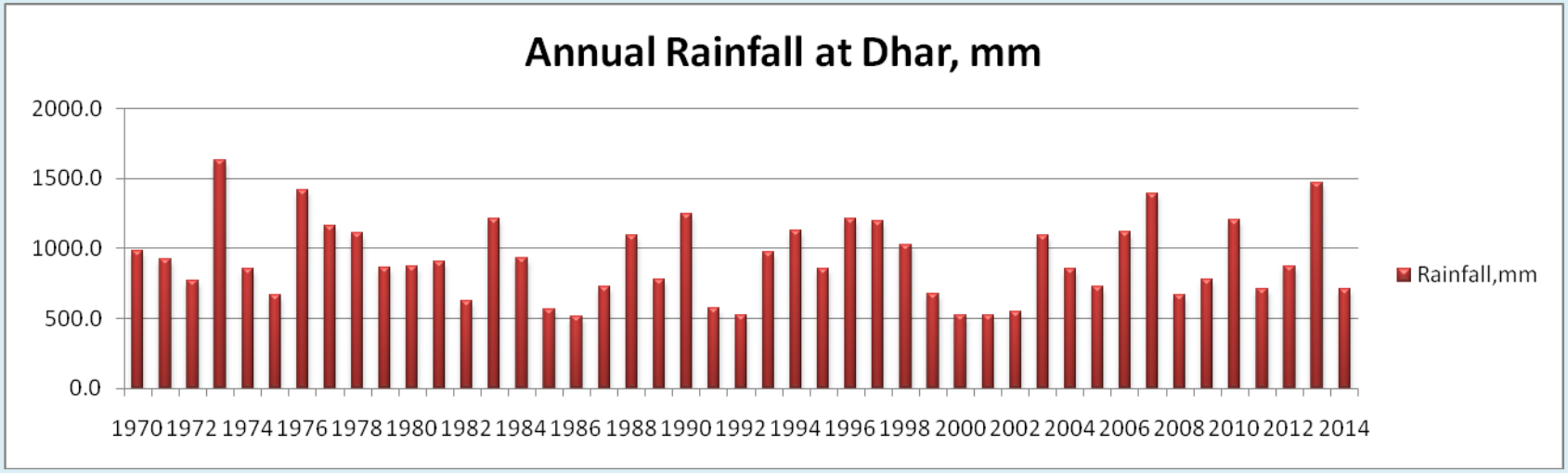
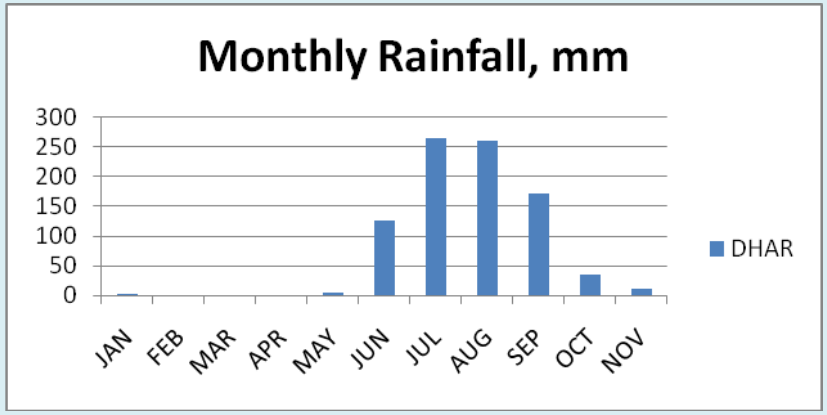


Fig. 64B Rainfall analysis at district Burhanpur, Agro-Climatic Zone –X, Nimar Plains





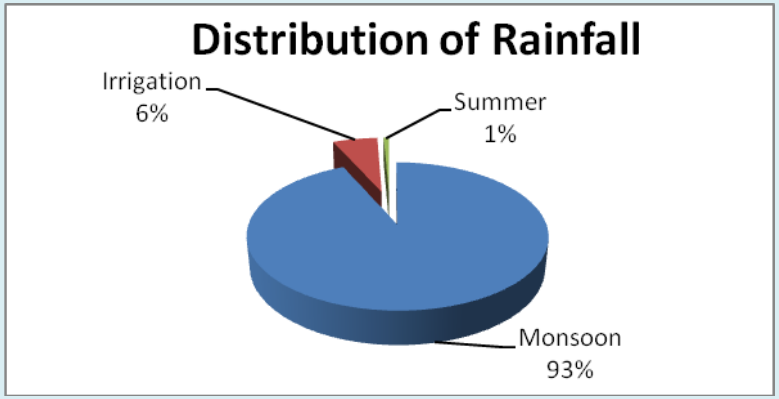
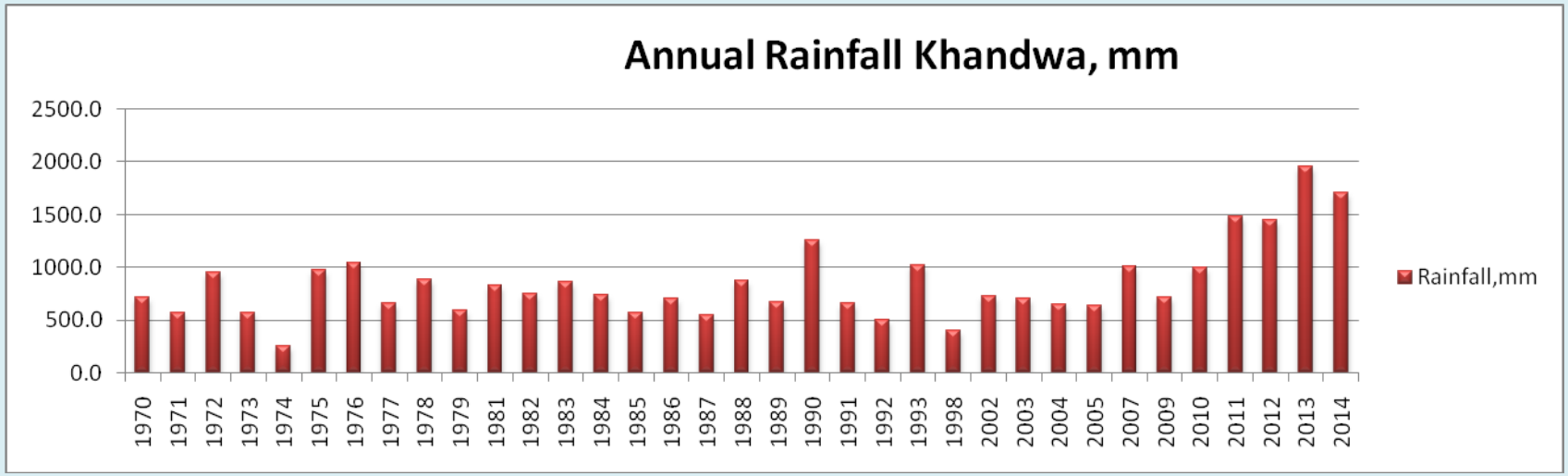
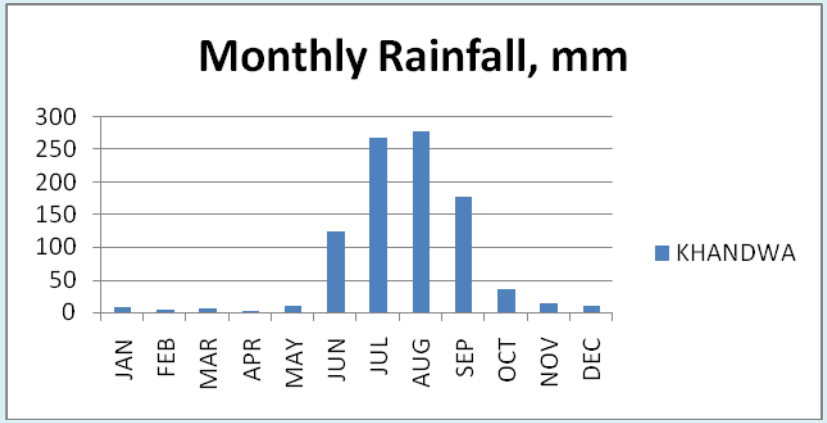


Fig. 64C Rainfall analysis at district Dhar, Agro-Climatic Zone –X, Nimar Plains





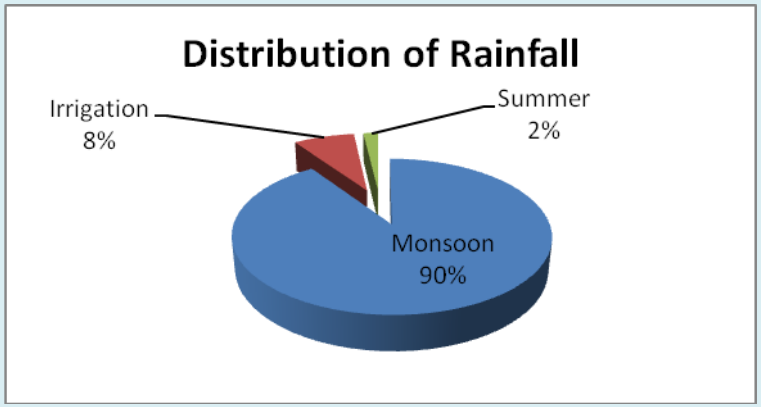
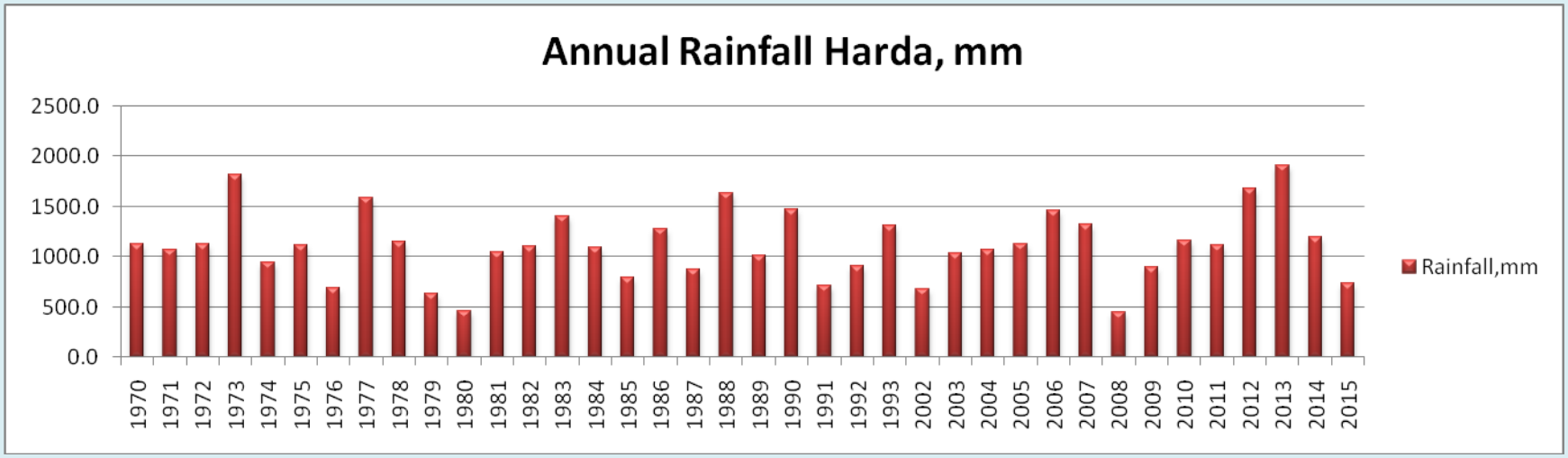
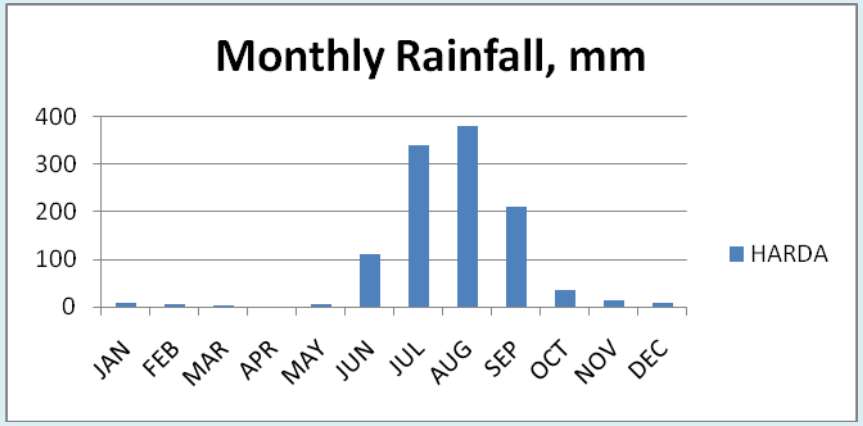


Fig. 64D Rainfall analysis at district Khandwa, Agro-Climatic Zone –X, Nimar Plains





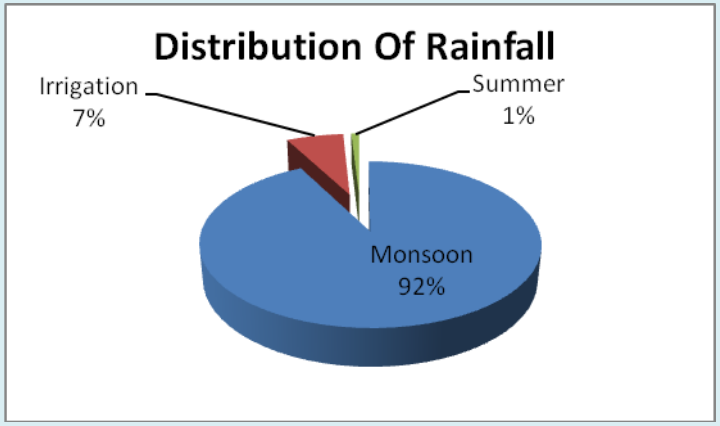
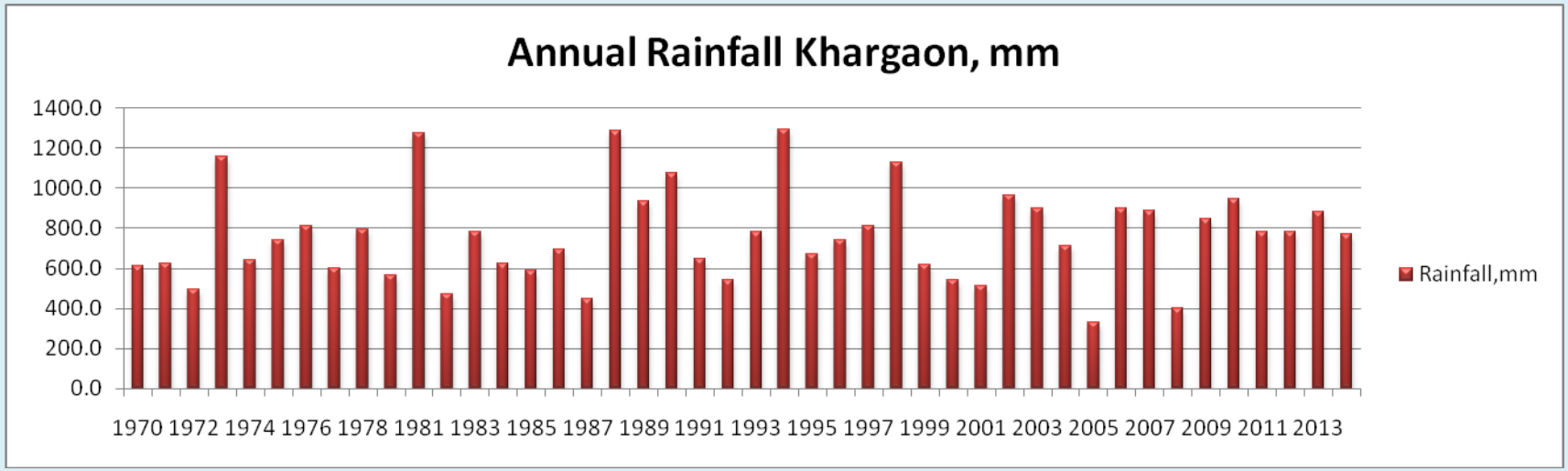
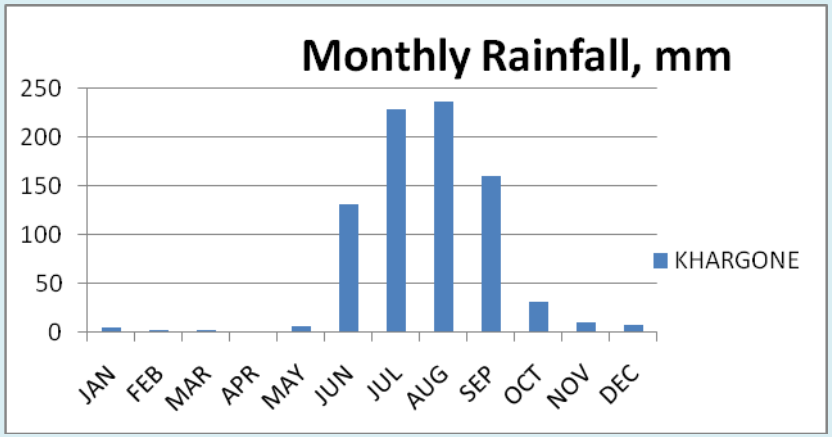


Fig. 64E Rainfall analysis at district Harda, Agro-Climatic Zone –X, Nimar Plains





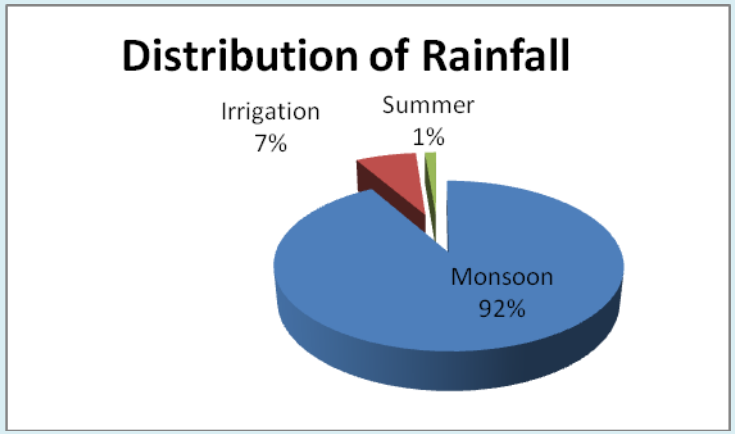


Fig. 64F Rainfall analysis at district Khargone, Agro-Climatic Zone –X, Nimar Plains

buffalo, bovine, sheep, goat, horses and ponnies, mules, donkey, pigs, dogs, rabbits, fowls, ducks, turkey and other poultry. The indigenous cattles are about 31 times more than the cross breed cattles and Dhar district has maximum percentage (10.3%) of cross breed cattle whereas Barwani has negligible (0.1%) of its cattle cross breed. This indicates that the zone has tremendous scope for breeding improvement programmes. As usual bovine (2913584) is the main cattle class found in the zone in which Dhar and Khargone together has share of 53.3%. Similarly these two districts also have share of 54.2% in total zonal buffalo (744612). Total bovine population of the zone is about four times more than the buffalo population. Dhar and Khargone along with Barwani shares 80.2 % of number of goats available at the zone. The sheep is mostly populated in Burhanpur (86.4%). Population of horses and ponies is maximum (4857) in this zone which is mostly populated in Dhar and Burhanpur. Other common animal of the zone is Fowls (1838297) and dogs (30088). Fowls are mostly populated in Dhar district (34.6%). The zone has only numeric numbers of animals like rabbits and mules. Total live stock water needs of the zone comes out 28592 ha m. It is maximum in Dhar (28.5%) followed by Khargone (24.9%), Barwani (17.4%), Khandwa (15.9%), Harda(7.4%), and Burhanpur (5.8%).

Water requirement of crops

The zone is a Cotton-Jowar zone has 94606 ha under Jowar and 482385 ha under cotton. Jowar is dominated in Barwani and Khargone aggregating 72.5% of the zone. Khargone is the leader in cotton cultivation as it occupies 45.6 % of zone. Wheat and soyabean is now mostly taken in the zone as wheat is being cultivated in 506820 ha in which Dhar (40.5%), Khargone (24.8%) and Khandwa (23.1%) are the main contributors. Soybean covers an area of 592659 ha in which Barwani, Dhar , and Khandwa are leading districts with 81.2% of zonal total. Other major crops are gram (134054 ha), groundnut and maize (148250 ha). Apart from this other pulses (kharif) are also taken in 43798 ha and Pigeon pea in 30527 ha. Dhar alone contributes with 70.3% gram coverage. Dhar is also leading in maize cultivation with 52938 ha area (35.7%), Table 39 A-B. Based on growing period, crop coefficient values, the water requirement of all the crops were worked out and presented in Table3. Total yearly water requirement of the crops of the zone is 1142786 ha m. The major user of water, in terms of crop water requirement, is Dhar district (29.2%) followed by Khargone

Table 39 A : Water requirement of field crops in Nimar Plains, ha m										
	Barwani		Burhanpur		Dhar		Khandawa		Khargone	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Rice	1092	785	919	694	664	489	3964	2973	1735	1313
Jowar (Kharif)	37107	16795	9023	4217	9628	4432	7336	3440	31512	15215
Jowar (Rabi)	1287	626	26	14	80	39	-	-	1	0
Bajra	5897	2239	69	27	2845	1098	155	61	409	166
Maize	39586	19650	9176	4703	52938	26728	14424	7418	32126	17012
Ragi	-	-	-	-	-	-	-	-	-	-
Wheat	47358	28999	11254	7716	205397	124416	117117	73604	125694	72819
Barley	-	-	-	-	13	8	-	-	-	-
Other Cereals and Millets (Kharif)	176	82	-	-	-	-	272	133	12	6
Other Cereals and Millets (Rabi)	4	2	-	-	20	11	-	-	-	-
Gram	4169	2350	3699	2335	94277	52564	19431	11240	12483	6657
Arhar(Tur)	4088	2375	2846	1749	2734	1621	6761	4070	14098	8466
Other Pulses (Rabi)	261	138	72	43	1689	884	2192	1190	89	45
Other Pulses (Kharif)	15261	6913	2140	1018	13511	6273	4541	2146	8345	3980
Sugarcane	2749	3613	5214	7383	1542	2034	339	457	-	-
Groundnut	9772	4993	428	226	2864	1489	2474	1310	7226	3939
Castor seed	158	191	2	3	121	146	332	413	1046	1256
Sesamum	265	129	94	48	167	83	1024	518	279	143
Rapeseed and	-	-	5	3	12	6	11	6	34	17

Mustard										
Linseed	-	-	-	-	3	2	25	14	13	7
Soyabean	37886	14382	18301	7173	292197	112817	189278	74434	54997	22271
Niger seed	-	-	-	-	-	-	-	-	-	-
Sunflower	-	-	1	0	-	-	43	17	-	-
Safflower	-	-	-	-	-	-	-	-	2	1
Other Oilseeds	-	-	-	-	26	14	-	-	-	-
Cotton	65882	49451	42221	33515	96409	73840	57663	44839	220210	170839
Jute	-	-	-	-	-	-	-	-	-	-
Mesta	17	11	-	-	-	-	4	3	42	29
Sanhemp	129	102	31	26	-	-	91	74	66	56
Other Fibres	-	-	10	7	-	-	2	1	-	-

Table 39 B Water requirement of fruits and vetables crops in Nimar Plains, ha m										
	Barwani		Burhanpur		Dhar		Khandwa		Khargone	
	Area	CWR	Area	CWR	Area	CWR	Area	CWR	Area	CWR
Chillies	6785	7399	199	237	11996	13091	8140	9072	22872	25182
Ginger	461	555	27	35	275	334	406	500	68	83
Turmeric	168	201	38	49	43	52	31	38	54	66
Betel nut	-	-	-	-	-	-	-	-	-	-
Garlic	179	287	11	19	5361	8571	98	161	31	51
Coriander	149	211	145	223	276	392	911	1332	875	1236
Other Condiments and Spices	32	40	-	-	909	1124	83	105	136	170
Mango	11	18	4	7	24	38	2	3	3	5
Banana	546	1132	17000	37737	648	1341	36	76	337	711
Citrus Fruits	130	167	51	70	346	445	15	20	88	115
Grapes	-	-	-	-	-	-	-	-	-	-
Papaya	331	543	35	61	193	316	33	55	336	560
Other Fruits	348	558	204	350	224	358	214	351	577	940
Potato	11	10	17	17	1489	1413	428	414	71	64
Sweet Potato	197	127	7	5	62	41	82	55	50	34
Onion	1523	2584	587	1066	2266	3836	7312	12688	1519	2621
Other Vegetables (Kharif)	1741	1127	326	222	2403	1594	2563	1730	736	501
Other Vegetables (Rabi)	2018	1517	443	373	2157	1604	1883	1452	963	685
Opium	-	-	-	-	-	-	-	-	-	-
Tobacco	-	-	-	-	-	-	-	-	-	-
Other Plantation Crops	1	2	-	-	79	141	4	7	60	109
Fodder Crops	1301	857	-	-	12184	8231	1698	1167	5987	4154
Other Non Food Crops	46	59	47	65	185	236	54	71	22	28

(25.2%), Khandwa (16.3%), Harda (11.7%), Barwani (10.5%) and Burhanpur (7.1%). Fig. 65-67 depicts crop water requirement of major crops in the districts of the zone.

This zone is known for chillies, garlic etc. and for fruit crop. Chillies are taken in 49992 ha with leading grower Khargone having 45.7% area followed by Dhar with 24.0% area. Garlic is cultivated in 5680 ha but mostly (94.4%) in Dhar. Onion is cultivated in 13207 ha but mostly in Khandwa (55.4%). Dhar and Khandawa dominate in cultivation of other vegetable in kharif and rabi with 63.9% area in kharif and with Barwani it reaches to 81.2%. Banana is mostly confined to Burhanpur with 17000ha area. Papaya is taken in 928 ha and other fruits are taken in 1567 ha. Fodder crops are also taken n big way in the zone with cultivated area of 21170 ha and Dhar is the main grower.

Water budget

The agroclimatic zone X (ACZ X)- Nimar Plains receives total quantum of water towards rainfall as 3452638 ha-m. Barwani, Khargone, Dhar and Khandwa each receives 20.1 to 17.4% of rainfall quantum. Minimum is in Burhanpur (9.7%). National Commission on Agriculture has laid down norms for water budgeting of an area and as per its estimate the losses of water as evaporation, surface water flow and ground water flow out of the area is calculated in present estimation. Similarly, addition of water into the area as runoff generated from the zone, addition of soil moisture and to the ground water is also computed. The water budget so generated for ACZ X is presented in Table 40. The immediate evaporation losses that occurs during the rainfall is taken as 17.5% of total rainfall and it is 604212 ha-m for the zone. 28.7% rainfall converts into surface flow and it is 990907 ha-m. It is considered that 10.549 % (164620 ha-m) of surface flow goes out of the zone. Ground water also adds to the surface flow and it is taken as 23.739% of surface flow. Thus, surface flow arrives to be 1560523 ha-m which is 45.198% of total precipitation.

Evaporation takes place from open water body, soil surface, forest and vegetation and also from rise of water table, and, respectively it is taken as 7.916% (123531 ha-m) of total surface flow, 31.504% (483981 ha-m) of total soil moisture storage, 30.826% (473565 ha-m) of total soil moisture and 18.451% (136914 ha-m) of total ground water. Part of rainfall as recharge enriches ground water and it is 12.5 % (431580 ha-m).

Table 40 : Water budgeting of Nimar plains, ha-m

S.N	Particulars	Barwani	Burhanpur	Dhar	Khandwa	Harda	Khargone	Zone Total
1	Normal rainfall, ha-m	693375	335509	682677	603119	454380	683578	3452638
2	Immediate evaporation (17.5%)	121341	58714	119468	105546	79517	119626	604212
3	Surface flow (28.7%)	198999	96291	195928	173095	130407	196187	990907
4	From outside state(10.549% of total surface flow)	33060	15997	32550	28756	21665	32593	164620
5	To GW from flood flows (-4.851% of total surface flow)	-15203	-7356	-14968	-13224	-9963	-14988	-75701
6	From GW to surface flow(23.739% of total surface flow)	74396	35999	73248	64712	48753	73345	370453
7	From irrigated area to surface flow(7.067% of total surface flow)	22147	10717	21806	19264	14514	21834	110282
8	Total surface flow(45.198% of total ppt)	313392	151643	308556	272598	205371	308964	1560523
9	Evaporation losses from reservoirs and tanks (7.916% of total surface flow)	24808	12004	24425	21579	16257	24458	123531
10	Flow into seas and outside state (43.445% of total surface flow)	136153	65881	134052	118430	89223	134229	677969
11	Utilizable surface flow (48.639% of total surface flow)	152431	73758	150079	132589	99890	150277	759023
12	Water available for ground water storage (12.5%)	86672	41939	85335	75390	56798	85447	431580
13	From streams and flood flows to GW(4.851% of total surface flow)	15203	7356	14968	13224	9963	14988	75701
14	From irrigation to GW addition (S.N.15-(12+13))	47146	22813	46418	41009	30895	46480	234760
15	Total GW (21.492% of total ppt)	149020	72108	146721	129622	97655	146915	742041
16	Evaporation and rise of water table (18.451% of total GW)	27496	13305	27071	23917	18018	27107	136914
17	Regeneration into streams(49.924% of total GW)	74397	35999	73249	64713	48753	73346	370457

18	GW available utilization(31.625% of total GW)	47128	22804	46400	40993	30884	46462	234670
19	Total utilizable surface + GW (S.N. 11+18)	199558	96562	196479	173582	130774	196739	993693
20	Soil moisture storage (41.3% of normal rainfall)	286364	138565	281946	249088	187659	282318	1425939
21	From irrigated area to soil moisture(7.067% of total surface flow)	22147	10717	21806	19264	14514	21834	110282
22	Total soil moisture storage (44.495% of total ppt)	308517	149285	303757	268358	202176	304158	1536251
23	Evaporation losses from soil moisture (31.504% of total soil moisture storage)	97195	47031	95696	84543	63694	95822	483981
24	Evap. losses from forest and other veg. (30.826% of total soil moisture)	95104	46019	93636	82724	62323	93760	473565
25	Soil moisture available for ET from crops (37.673 % of total soil moisture)	116228	56240	114434	101098	76166	114585	578752
26	Water requirement of crops	119577	81324	333921	186376	133714	287871	1142783
27	Water requirement of animal husbandry	4986	1651	8162	4542	2114	7136	28591
28	Domestic water requirement	8382	3730	10765	6452	2810	9226	41365
29	Industrial Water requirement @ 6 % of available fresh water	26068	12525	40705	30610	25603	45372	180883
30	Water available for utilization (S.N. 19+25)	315786	152802	310914	274680	206940	311324	1572445
31	Water required for different sectors (26+27+28+29)	159013	99230	393553	227980	164241	349605	1393622
32	Surplus or deficit of water in the district (30-31)	156773	53572	-82639	46700	42699	-38281	178823

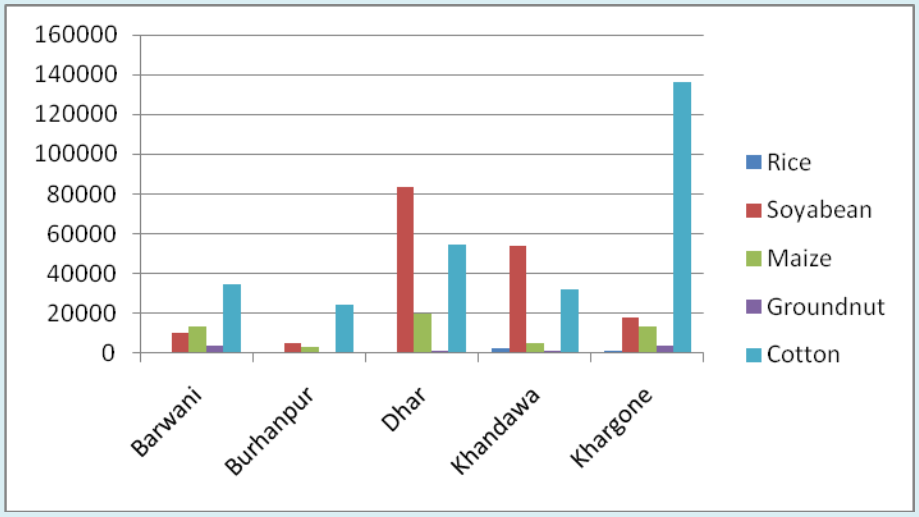


Fig. 65 Crop water requirement of major kharif crops of ACZ X-Nimar Plains in ha m

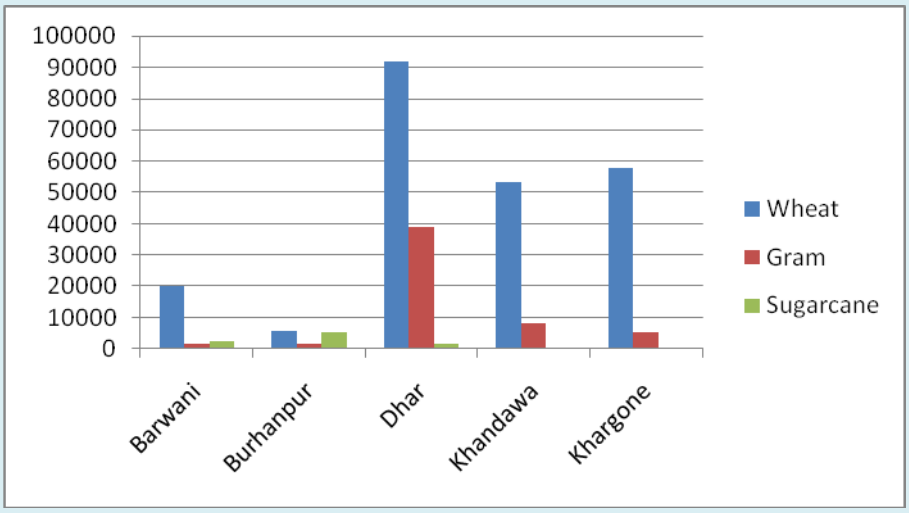


Fig. 66 Crop water requirement of major rabi crops of ACZ X -Nimar Plains in ha m

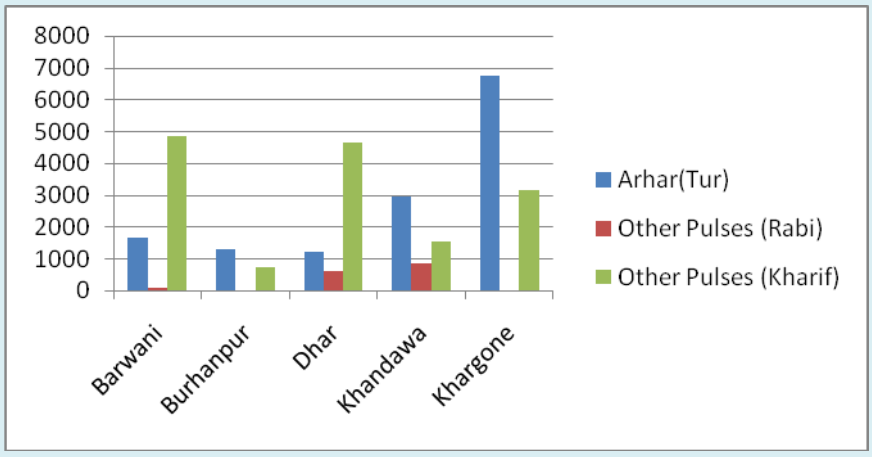


Fig. 67 Crop water requirement of pulse crops of ACZ X -Nimar Plains in ha m

There is an addition to the ground water from streams and flood flows which is -4.851 % (-75701 ha-m) of total surface flow. The total utilizable surface and ground water for the ACZ X computed as 993693 ha-m.

The soil moisture increases due to rainfall as well as from irrigation. 41.3% of rainfall and 7.067% of total surface flow is considered as soil moisture storage. Total zonal soil moisture storage is 1536251 ha-m and out of this 578752 ha-m is available as ET for the crops. Each and every district of the ACZ X zone contributes in same proportion in zonal water budgeting as the quantum of rainfall of each district contributes in zonal rainfall quantum owing to rainfall based water distribution.

Utilization of water takes place in four major categories. These are, domestic and animal water needs, crop water requirement and requirement of water for industrial and recreation. A water need of different sectors in districts of ACZ X is presented in Fig. 68. Total crop water requirement of the zone is 1142786 ha-m and out of which Dhar and Khargone together needs water towards crops as 54.4% of zonal total. The least crop water demand comes from Burhanpur with 7.1% water needs towards crop. In comparison to the crop water demand the water demand towards domestic and animal husbandry is very low as it is respectively 41366 ha m and 28592 ha m. Owing to higher population in Dhar the domestic demand is about 26.0% of the zonal demand. Burhanpur registers the least domestic water demand i.e. only 5.8% Dhar and Khargone have more animal population and together needs 53.5% of zonal total. The industrial demand is computed as 6% of available water thus total zonal demand comes out as 180886 ha m.

Total water needs and supply of different districts of ACZ X is presented in Fig. 69. The excess/deficit of water is also shown in the figure. The water available for utilization at zonal level is 1572445 ha m. Barwani, Dhar and Khargone have more or less equal water about 20% for utilization. Other districts have Khandwa (17.5%), Harda (13.2%) and Burhanpur (9.7%). The total zonal water demand is 1412934 ha m which gives an excess of 159511 ha m at zonal level. Two districts Dhar (-18%) and Khargone (-12%) has deficient water for their requirement. All other districts namely Barwani (95%), Burhanpur (36%), Khandwa (21%) and Harda (16%) have excess water but the zonal level the surplus water is only 11%. An abstract in pictorial form is provided in Fig 70.

Taking net sown area of these district, as per Directorate of Extension and Farmers Welfare, 229648 ha, 104016 ha, 501898 ha, 303834 ha, 182397 ha and 402304 ha, the per hectare water excess/deficit comes out to be 67 cm, 39 cm, -14 cm, 16 cm, 16 cm and -11 cm with availability of 9 cm/ha at zonal level. It means, the future plans to enhance crop production or alternate cropping may be based on this much depth of water.

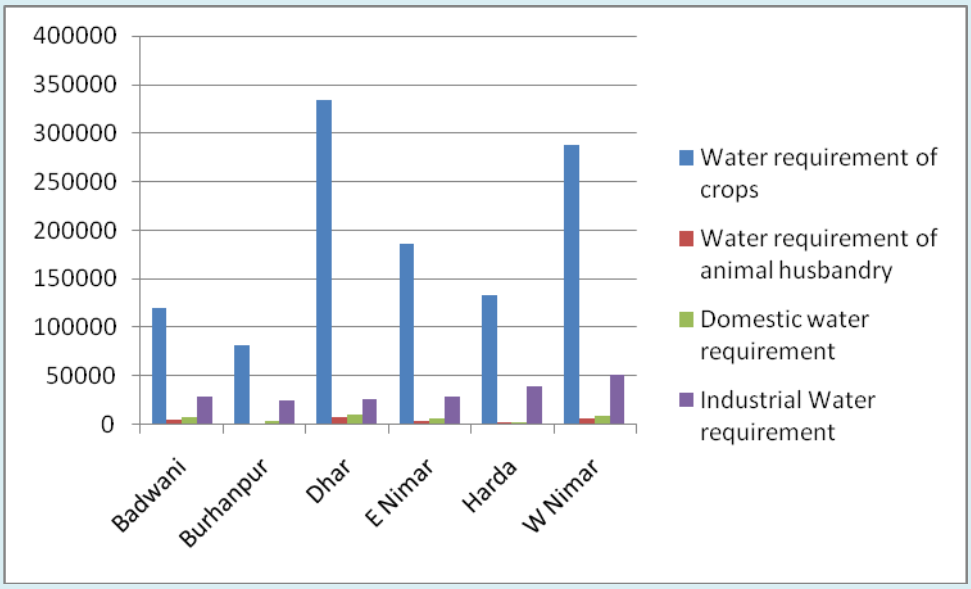


Fig. 68 Water needs of different sectors in districts of ACZ X - Nimar Plains (ha-m)

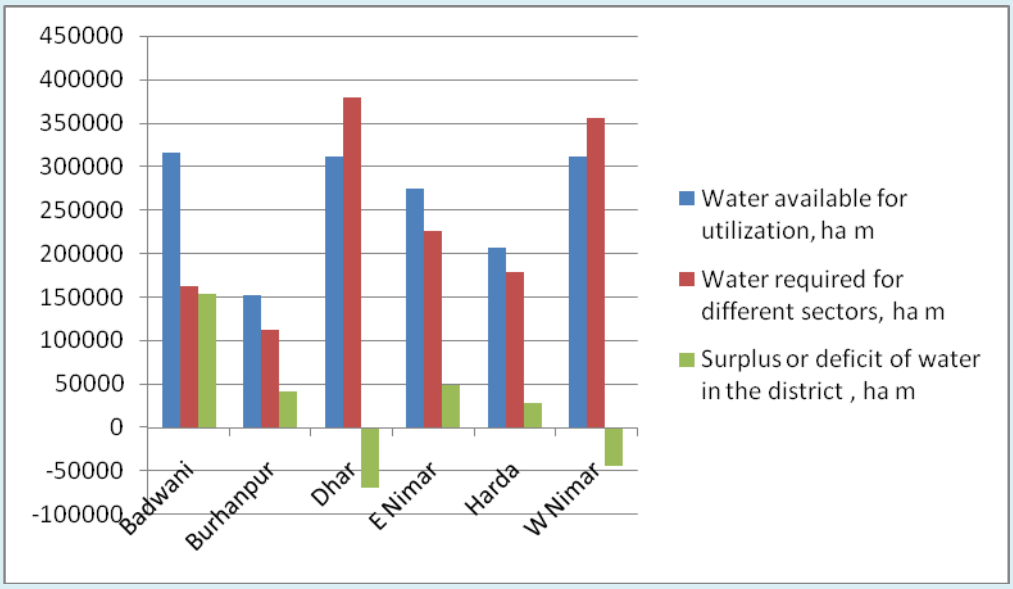


Fig. 69 Total Water needs and supply of different districts of ACZ X - Nimar Plains (ha-m)

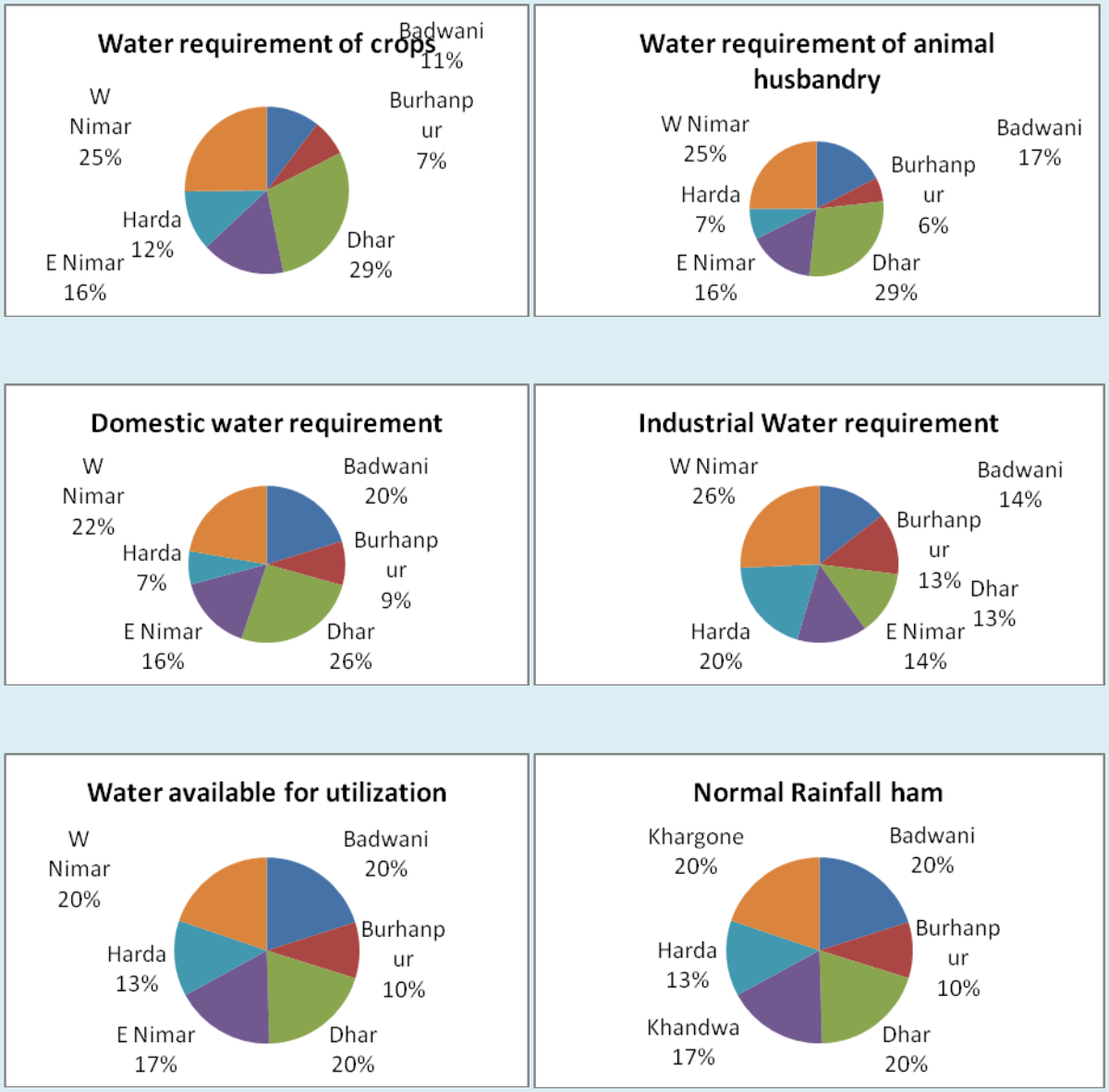


Fig. 70 Abstract of water of different districts of ACZ X - Nimar Plains (ha-m)

Agroclimatic Zone XI - Jhabua Hills

The Agroclimatic zone XI – Jhabua Hills comprises of two districts; Alirajpur and Jhabua. It comes under Cotton-Jowar zone having medium black skeletal (light/medium) soils. The zone has total geographical area of 675716 ha, out of which forest area is 19.5 %. Net area sown is 53.3 %. Out of total net sown area of 360519 ha, the fallow land including current fallow is 2.4%. District land utilization is presented in Table 41.

Rainfall analysis

Annual normal rainfall is 800 to 1000 mm. On an average 93 % of this rainfall occurs during monsoon i.e. June to September, 6% in winter i.e. late December and 1% in summer. Maximum rainfall occurs in the month of July followed by the month August. The pattern of annual rainfall occurred in years 1970 to 2014 is presented in Fig. 71 A-B. The record also shows maximum ever rainfall of 1690 mm (2006) was occurred in the Alirajpur. The annual rainfall exceeded 53% times than the normal annual rainfall.

Domestic and livestock water needs

Total population of the zone is 1752768 as per Census 2011. A total human water need of the zone is 8637 ha-m. Table 42 illustrates water requirement towards human needs as well as for live stock. Live stock population comprises of cattle both cross breed and indigenous, buffalo, bovine, sheep, goat, horses and ponnies, mules, donkey, pigs, dogs, rabbits, fowls, ducks, turkey and other poultry. The indigenous cattles are about 47 times more than the cross breed cattle. The most of the cross breed cattles are with Jhabua (96%) whereas indigenous cattles are more in number in Alirajpur than Jhabua. Both districts have scope of breeding improvement programmes. In comparison to buffalo, bovine dominates in the zone. Out of available bovine (1009953) in the zone almost equal in numbers are found in both the districts, whereas in case of buffalo (160300) the ratio of availability in Alirajpur and Jhabua is 3:5. About 60% of total fowls (1117882), 54 % of total goats (576698), 62 % of total dogs (41269) and 92 % of total ducks (5267) are found in Alirajpur. All other animals found in these two districts are more or less of the same quantity.

Table 41 -Total Area and Classification of Area In Each District of Jhabua Hills MADHYAPRADESH State for the year ending 2013- 14

DISTRICT NAME	Reporting Area For Land Utilization Statics	Forests	Area Under Non Agricultural Uses	Not Available For Cultivation			Other Uncultivated Land Excluding Fallow Land			Fallow Land		Total	Net Area Sown	Total Cropped Area	Area Sown more than once
				Barren and Unculturable Land	Total	Permanent Pastures and Other Grazing Lands	Land Under Misc Tree crops and Groves not Included in Net Area	Culturable Waste Land	Total	Fallow Lands Other than Current Fallows	Current Fallows				
(1)	(2)	(3)	(4)	(5)	6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
ALIRAJPUR	382659	121107	26353	47657	74010	3208	0	7217	10425	2219	4157	6376	170741	211745	41004
JHABUA	293057	10963	32358	35030	67388	4455	4	18092	22551	1237	1140	2377	189778	255431	65653
Total	**675716**	**132070**	**58711**	**82687**	**141398**	**7663**	**4**	**25309**	**32976**	**3456**	**5297**	**8753**	**360519**	**467176**	**106657**
State Total	**30756303**	**8690816**	**2161511**	**1345764**	**3507275**	**1290895**	**19522**	**1008120**	**2318537**	**468118**	**349500**	**817618**	**15422057**	**24047027**	**8624970**
				Total Geographical Area of the State is					30824500						

Table 42 : Live stock and Human water needs of ACZ XI			
	Alirajpur	Jhabua	Zone Total
Cross breed Cattle	431	17409	17840
Water Req. (l/day)	64650	2611350	2676000
Indigenous Cattle	440049	391764	831813
Water Req. (l/day)	44004900	39176400	83181300
Buffalo	57493	102807	160300
Water Req. (l/day)	8623950	15421050	24045000
Bovine	497973	511980	1009953
Water Req. (l/day)	74695950	76797000	151492950
Sheep	1940	3024	4964
Water Req. (l/day)	19400	30240	49640
Goat	310263	266435	576698
Water Req. (l/day)	3102630	2664350	5766980
Horse & Ponies	26	39	65
Water Req. (l/day)	845	1267.5	2112.5
Mules	0	1	1
Water Req. (l/day)	0	32.5	32.5
Donkey	381	253	634
Water Req. (l/day)	12382.5	8222.5	20605
Camels	0	0	0
Water Req. (l/day)	0	0	0
Pigs	146	0	146
Water Req. (l/day)	1460	0	1460
Dogs	25476	15793	41269
Water Req. (l/day)	127380	78965	206345
Rabbits	144	75	219
Water Req. (l/day)	92.16	48	140.16
Elephants	153	32	185
Water Req. (l/day)	22950	4800	27750
Fowls	660217	457665	1117882
Water Req. (l/day)	165054.25	114416.25	279470.5
Ducks	4831	436	5267
Water Req. (l/day)	1207.75	109	1316.75
Turkeys	26	22	48
Water Req. (l/day)	6.5	5.5	12
Other Poultry	0	11	11
Water Req. (l/day)	0	2.75	2.75
TWR lpd	132842407	138676005	271518412
TWR ha m	4776	4997	9773
Human Population	728677	1024091	1752768
TWR human, ha m	3591	5046	8637

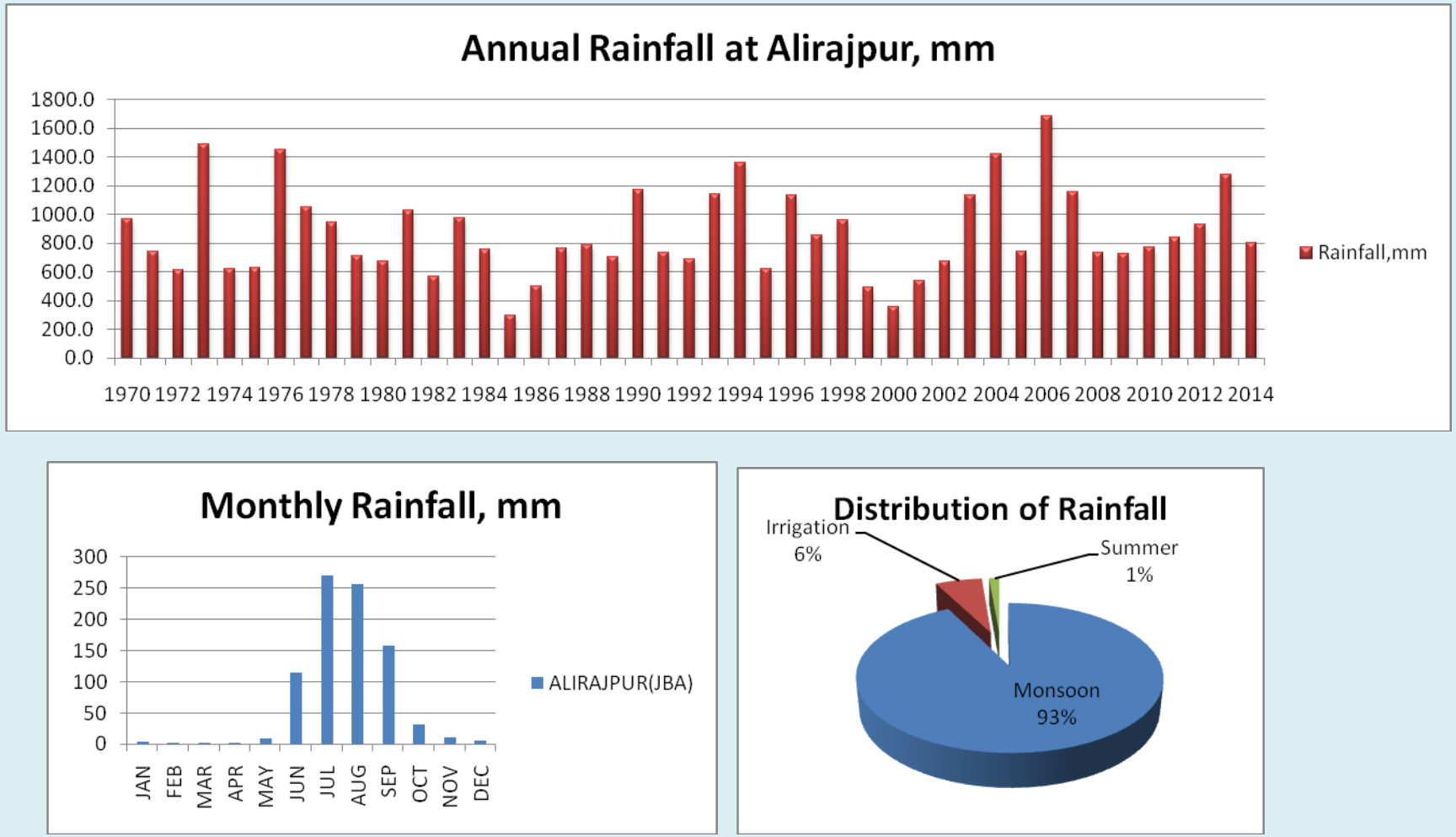
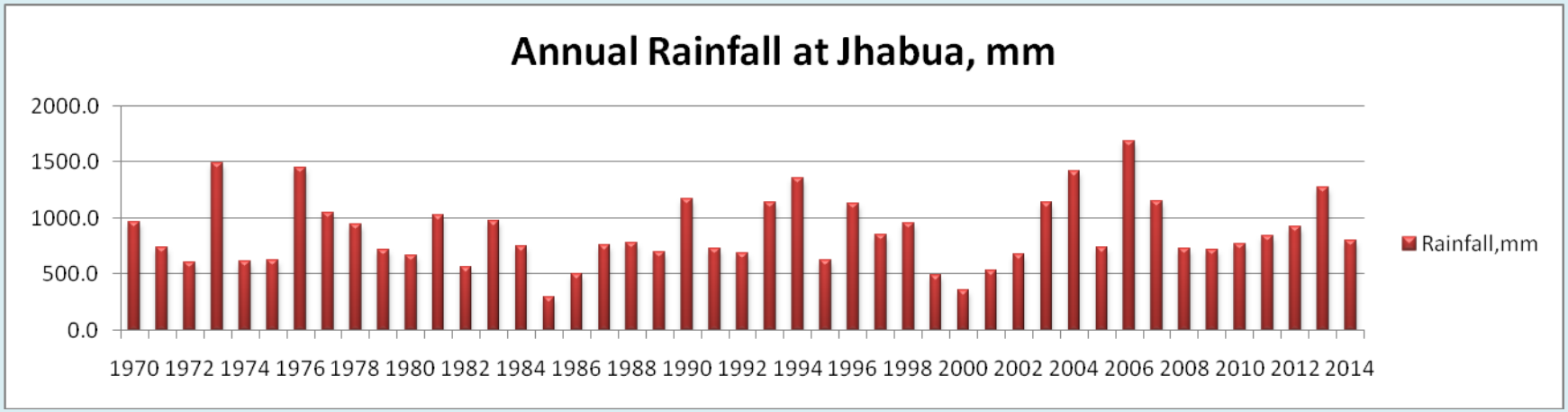
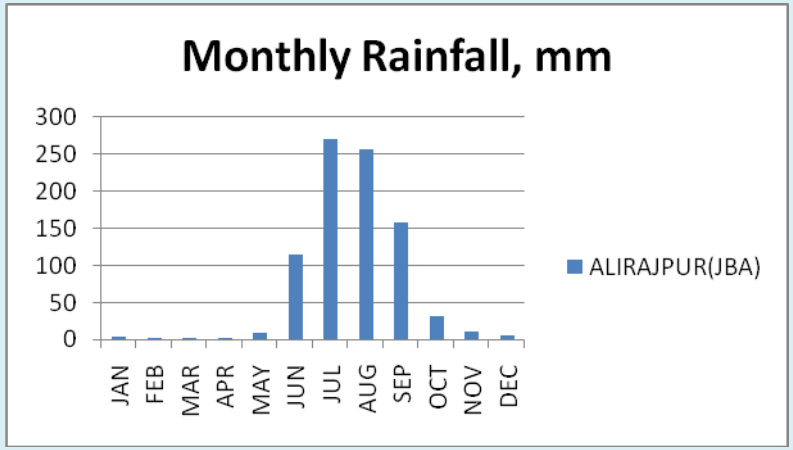


Fig. 71A Rainfall analysis at district Alirajpur, Agro-Climatic Zone –X, Jhabua Hills





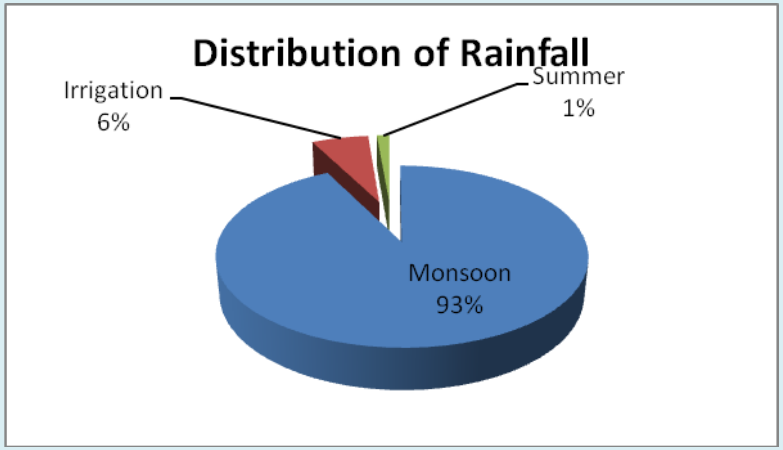


Fig. 71B Rainfall analysis at district Jhabua, Agro-Climatic Zone –X, Jhabua Hills

Water requirement of crops

The zone is a Cotton- Jowar zone but 84% of zonal total jowar (15895 ha) is taken in Alirajpur while 76 % of total cotton (28715 ha) is taken in Jhabua district. Maize and soyabean have replaced jowar in kharif as in total 105554 ha and 73848 ha area under the zone. The ratio of area under these two crops i.e. Maize and Soybean is respectively 2:3 and 1:3 for Alirajpur and Jhabua. Other kharif pulses also occupies a good area (73349 ha) and 87% of which lies in Alirajpur. Table 43 A-B. Based on growing period, crop coefficient values, the water requirement of all the crops were worked out and presented in Table 43A. However, based on irrigated area the water requirement of major crops were also calculated and presented Fig. 72 to Fig 74.

It is a small zone having 2524 ha under Chillies mostly in Jhabua, Onion in 533 ha, other vegetables in kharif is 3786 ha and in rabi other vegetable covers an area of 1329 ha. Fodder crops are taken mostly in Jhabua district with zonal cultivated area as 9556 ha.

Water budget

The agroclimatic zone XI (ACZ XI)- Jhabua Hills receives total quantum of water towards rainfall as 578074 ha-m. National Commission on Agriculture has laid down norms for water budgeting of an area and as per its estimate the losses of water as evaporation, surface water flow and ground water flow out of the area is calculated in present estimation. Similarly, addition of water into the area as runoff generated from the zone, addition of soil moisture and to the ground water is also computed. The water budget so generated for ACZ XI is presented in Table 44. The immediate evaporation loss that occurs during the rainfall is taken as 17.5% of total rainfall and it is 101163 ha-m for the zone. 28.7% rainfall converts into surface flow and it is 165907 ha-m. It is considered that 10.549 % (27562 ha-m) of surface flow goes out of the zone. Ground water also adds to the surface flow and it is taken as 23.739% of surface flow. Thus, surface flow arrives to be 261278 ha-m which is 45.198% of total precipitation.

Evaporation takes place from open water body, soil surface, forest and vegetation and also from rise of water table, and, respectively it is taken as 7.916% (20683 ha-m) of total surface flow, 31.504% (81033 ha-m) of total soil moisture storage, 30.826% (79289 ha-m) of total soil moisture and 18.451% (22923 ha-m) of total ground water. Part of rainfall as recharge enriches ground water and it is 12.5 % (72259 ha-m).

Table 43 A : Water requirement of field crops in Jhabua Hills, ha m				
Crops	Alirajpur		Jhabua	
	Area	CWR	Area	CWR
Rice	6947	5057	11867	8639
Jowar (Kharif)	13289	6138	2606	1204
Jowar (Rabi)	1212	557	1	0
Bajra	13619	5276	3	1
Maize	38841	19677	66713	33797
Ragi	-	-	-	-
Wheat	21006	12339	44031	25864
Barley	49	27	163	91
Other Cereals and Millets (Kharif)	1326	627	286	135
Other Cereals and Millets (Rabi)	-	-	-	-
Gram	10224	5528	16628	8990
Arhar (Tur)	2639	1526	2539	1468
Other Pulses (Rabi)	354	180	410	208
Other Pulses (Kharif)	63680	29206	9669	4435
Sugarcane	8	11	11	15
Groundnut	10067	5250	6593	3438
Castor seed	513	609	163	194
Sesamum	310	152	218	107
Rapeseed and Mustard	-	-	3	2
Linseed	-	-	-	-
Soyabean	16990	6582	56858	22027
Niger seed	-	-	-	-
Sunflower	-	-	-	-
Safflower	-	-	-	-
Other Oilseeds	-	-	1	1
Cotton	7870	5879	20845	15571
Jute	-	-	-	-
Mesta	21	14	-	-
Sanhemp	42	35	71	60
Other Fibres	-	-	-	-

Table 43 B : Water requirement of fruits and vetables crops in Jhabua Hills, ha m				
Crops	Alirajpur		Jhabua	
	Area	CWR	Area	CWR
Chillies	529	601.47	1995	2268.32
Ginger	27	32.78	53	64.35
Turmeric	81	97.95	15	18.14
Betel nut	0	0.00	0	0.00
Garlic	150	246.46	204	335.18
Coriander	66	92.20	2	2.79
Other Condiments and Spices	30	38.66	10	12.89
Mango	3	4.93	1	1.64
Banana	0	0.00	0	0.00
Citrus Fruits	1	1.32	1	1.32
Grapes	0	0.00	0	0.00
Papaya	0	0.00	18	30.27
Other Fruits	5	8.22	12	19.72
Potato	0	0.00	18	16.55
Sweet Potato	9	5.90	34	22.28
Onion	194	337.50	339	589.76
Other Vegetables (Kharif)	477	312.53	3309	2168.06
Other Vegetables (Rabi)	784	565.19	545	392.89
Opium	0	0.00	0	0.00
Tobacco	0	0.00	0	0.00
Other Plantation Crops	0	0.00	0	0.00
Fodder Crops	377	251.58	9179	6125.45
Other Non Food Crops	5	6.29	17	21.37

Table 44 : Water budgeting of Jhabua hills, ha-m

S.N	Particulars	Alirajpur	Jhabua	Zone Total
1	Normal rainfall, ha-m	327364	250710	578074
2	Immediate evaporation (17.5%)	57289	43874	101163
3	Surface flow (28.7%)	93953	71954	165907
4	From outside state(10.549% of total surface flow)	15609	11954	27562
5	To GW from flood flows (-4.851% of total surface flow)	-7178	-5497	-12675
6	From GW to surface flow(23.739% of total surface flow)	35125	26900	62025
7	From irrigated area to surface flow (7.067% of total surface flow)	10456	8008	18465
8	Total surface flow(45.198% of total ppt)	147962	113316	261278
9	Evaporation losses from reservoirs and tanks (7.916% of total surface flow)	11713	8970	20683
10	Flow into seas and outside state (43.445% of total surface flow)	64282	49230	113512
11	Utilizable surface flow (48.639% of total surface flow)	71967	55116	127083
12	Water available for ground water storage (12.5%)	40921	31339	72259
13	From streams and flood flows to GW(4.851% of total surface flow)	7178	5497	12675
14	From irrigation to GW addition (S.N.15-(12+13))	22259	17047	39306
15	Total GW (21.492% of total ppt)	70357	53883	124240
16	Evaporation and rise of water table (18.451% of total GW)	12982	9942	22923

17	Regeneration into streams(49.924% of total GW)	35125	26900	62025
18	GW available utilization(31.625% of total GW)	22250	17040	39291
19	Total utilizable surface + GW (S.N. 11+18)	94218	72156	166374
20	Soil moisture storage (41.3% of normal rainfall)	135201	103543	238745
21	From irrigated area to soil moisture(7.067% of total surface flow)	10456	8008	18465
22	Total soil moisture storage (44.495% of total ppt)	145661	111553	257214
23	Evaporation losses from soil moisture (31.504% of total soil moisture storage)	45889	35144	81033
24	Evap. losses from forest and other veg. (30.826% of total soil moisture)	44901	34387	79289
25	Soil moisture available for ET from crops (37.673 % of total soil moisture)	54875	42026	96900
26	Water requirement of crops	62850	88529	151379
27	Water requirement of animal husbandry	4776	4997	9773
28	Domestic water requirement	3591	5046	8637
29	Industrial Water requirement @ 6 % of available fresh water	15111	15951	31062
30	Water available for utilization (S.N. 19+25)	149092	114182	263274
31	Water required for different sectors (26+27+28+29)	86328	114523	200851
32	Surplus or deficit of water in the district (30-31)	62764	-341	62423

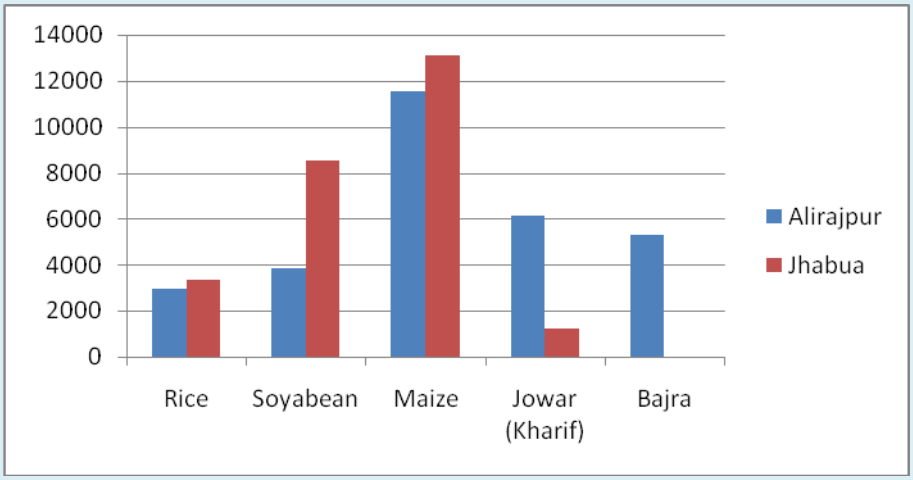


Fig. 72 Crop water requirement of major kharif crops of ACZ XI - Jhabua Hills in ha m

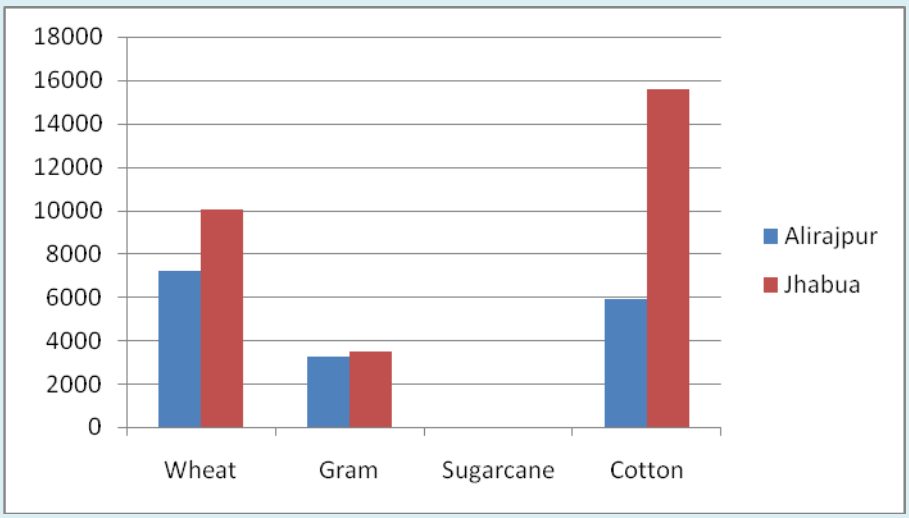


Fig. 73 Crop water requirement of major rabi crops of ACZ XI - Jhabua Hills in ha m

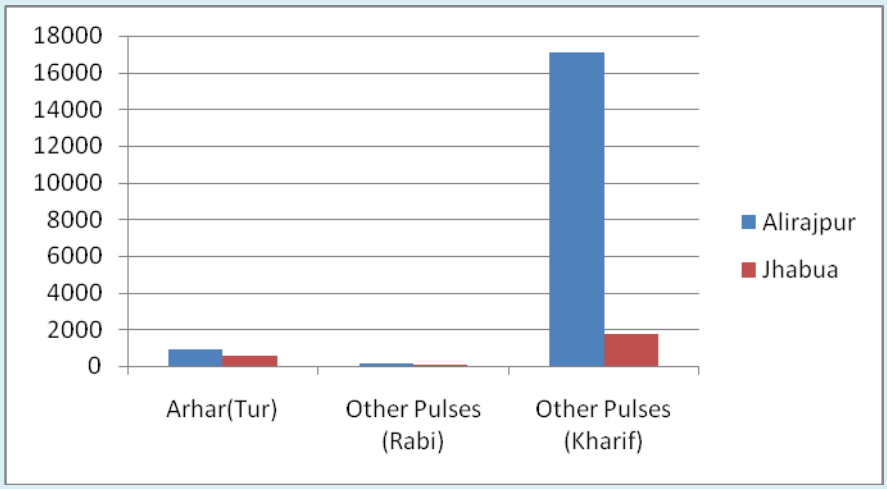


Fig. 74 Crop water requirement of pulse crops of ACZ XI - Jhabua Hills in ha m

There is movement to ground water from streams and flood flows which is - 4.851 % (-12675 ha-m) of total surface flow. The total utilizable surface and ground water for the ACZ XI computed as 166374 ha-m.

The soil moisture increases due to rainfall as well as from irrigation. 41.3% of rainfall and 7.067% of total surface flow is considered as soil moisture storage. Total zonal soil moisture storage is 257214 ha m and out of this 96900 ha-m is available as ET for the crops.

Utilization of water takes place in four major categories. These are, domestic and animal water needs, crop water requirement and requirement of water for industrial and recreation. Water needs of different sectors in districts of ACZ XI are presented in Fig. 75. Total crop water requirement of the zone is 151379 ha-m. In comparison to the crop water demand the water demand towards domestic and animal husbandry is very low as it is respectively 8637 ha-m and 9773 ha-m. The industrial demand is computed as 6% of available water thus total zonal demand comes out as 31062 ha-m.

Total water needs and supply of different districts of ACZ XI is presented in Fig. 76. The excess of water is also shown in the figure. The water available for utilization at zonal level is 263274 ha-m. As for as the excess water concerns the zone has 39398 ha-m of surplus water and this is 18 %. Considering net sown area as 360519 ha the average depth of excess water available per hectare is 11 cm. At district level the per unit hectare water availability in Alirajpur is 29 cm while it is -5 cm in Jhabua district. It means, the future plans to enhance crop production or alternate cropping may be based on this much depth of water. An abstract in pictorial form is provided in Fig 77.

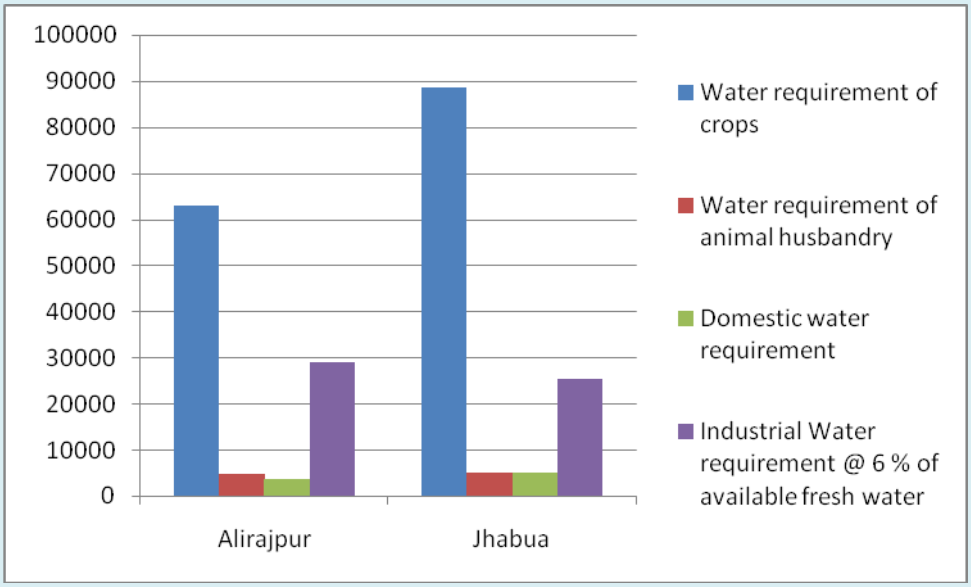


Fig. 75 Water needs of different sectors in districts of ACZ XI - Jhabua Hills (ha-m)

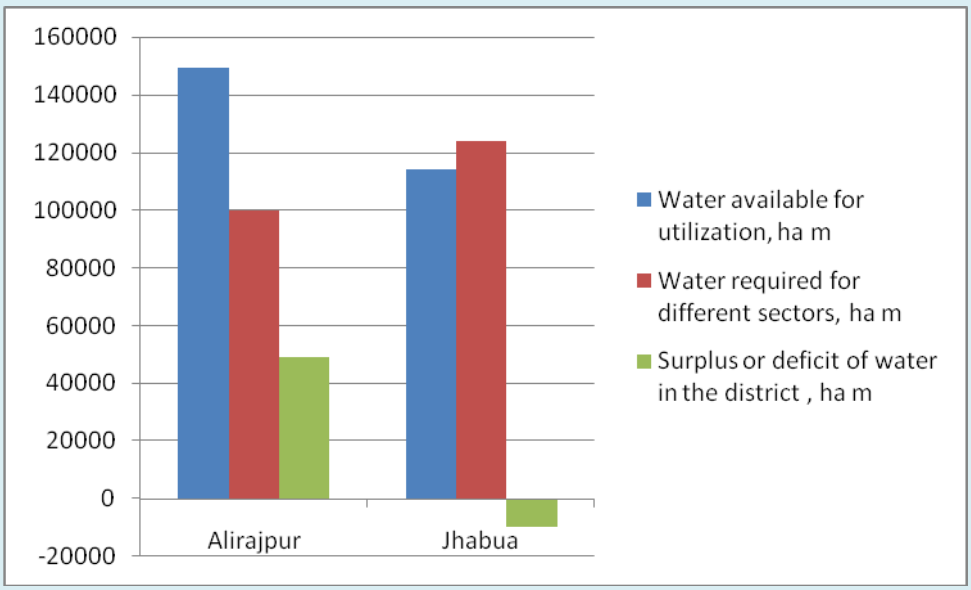


Fig. 76 Total Water needs and supply of different districts of ACZ XI - Jhabua Hills (ha-m)

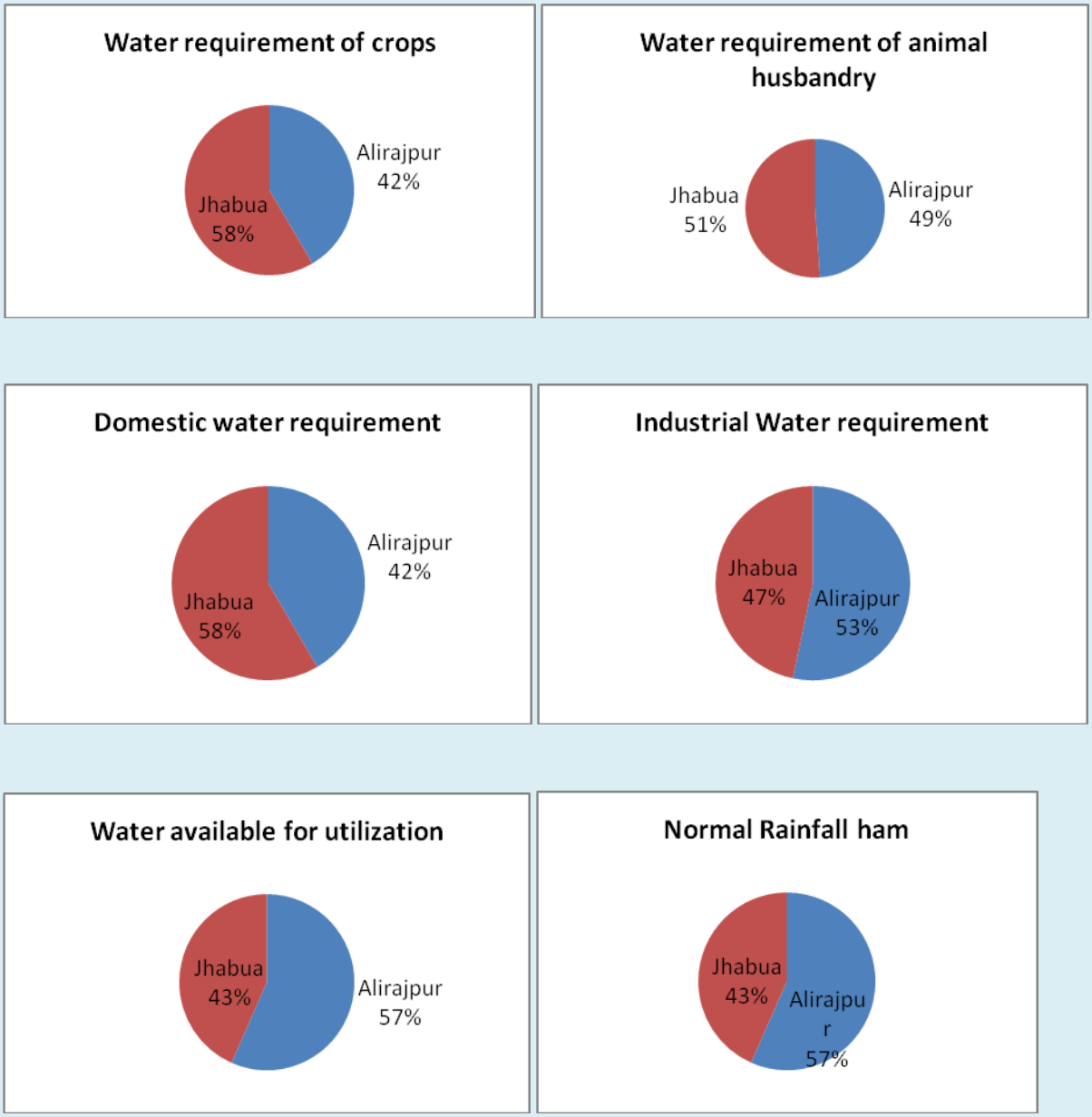


Fig. 77 Abstract of water of different districts of ACZ XI - Jhabua Hills (ha-m)

District Wise Water Budget of Madhya Pradesh at a Glance

Particulars	Water available for utilization, ha-m	Water required for different sectors, ha-m	Surplus or deficit of water in the district , ha-m	Percentage Excess/ Deficit (1-2)
Ashoknagar	187748	212540	-24792	-12
Agar Malwa	115079	146582	-31503	-21
Alirajpur	149092	100052	49040	49
Anuppur	210840	100851	109989	109
Badwani	315786	161780	154006	95
Balaghat	355111	82017	273094	333
Betul	496301	237275	259026	109
Bhind	159451	180393	-20942	-12
Bhopal	136629	132939	3690	3
Burhanpur	152802	111957	40845	36
Chhatarpur	430434	308364	122070	40
Chhindwara	545049	279550	265499	95
Damoh	388363	231439	156924	68
Datia	122591	171257	-48666	-28
Dewas	340159	289247	50912	18
Dhar	310914	379238	-68324	-18
Dindori	225050	118462	106588	90
Guna	245617	246301	-684	0
Gwalior	158905	181888	-22983	-13
Harda	206940	178113	28827	16
Hoshangabad	437841	331278	106563	32
Indore	167653	225269	-57616	-26
Jabalpur	290449	240112	50337	21
Jhabua	114182	123824	-9642	-8
Katni	262972	192792	70180	36
Khandwa	274680	226195	48485	21
Khargone	311324	355651	-44327	-12
Mandla	635483	151790	483693	319
Mandsor	199189	302263	-103074	-34
Morena	161470	206956	-45486	-22
Narsinghpur	290803	234035	56768	24
Nimach	146796	188042	-41246	-22
Panna	378687	181845	196842	108
Raisen	478390	320963	157427	49
Rajgarh	235212	375824	-140612	-37
Ratlam	207930	263337	-55407	-21
Rewa	327299	221174	106125	48
Sagar	557840	384400	173440	45
Satna	364401	256019	108382	42
Sehore	376953	360020	16933	5

Seoni	525309	217452	307857	142
Shahdol	313244	142511	170733	120
Shajapur	146093	214047	-67954	-32
Sheopur	286612	163008	123604	76
Shivpuri	365856	314302	51554	16
Sidhi	252670	118015	134655	114
Singrauli	303962	132551	171411	129
Tikamgarh	245676	247833	-2157	-1
Ujjain	247204	360357	-113153	-31
Umaria	281944	82937	199007	240
Vidisha	331325	349095	-17770	-5
State Total	14772308	11334142	3438166	30

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