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Vijay P. Singh
Shalini Yadav
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Water Resources Management

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Preface

Fundamental to sustainable economic development, functioning of healthy ecosystems, reliable agricultural productivity, dependable power generation, maintenance of desirable environmental quality, continuing industrial growth, enjoyment of quality lifestyle, and renewal of land and air resources is water. With growing population, demands for water for agriculture and industry are skyrocketing. On the other hand, freshwater resources per capita are decreasing. There is therefore a need for effective water resources management strategies. These strategies must also consider the nexus between water, energy, environment, food, and society. With these considerations in mind, the International Conference on Water, Environment, Energy and Society (WEES-2016) was organized at AISECT University in Bhopal, MP, India, during March 15–18, 2016. The conference was fifth in the series and had several objectives.

The first objective was to provide a forum to not only engineers, scientists, and researchers, but also practitioners, planners, managers, administrators, and policy-makers from around the world for discussion of problems pertaining to water, environment, and energy that are vital for the sustenance and development of society.

Second, the Government of India has embarked upon two large projects: one on cleaning of River Ganga and the other on cleaning River Yamuna. Further, it is allocating large funds for irrigation projects with the aim to bring sufficient good-quality water to all farmers. These are huge ambitious projects and require consideration of all aspects of water, environment, and energy as well as society, including economics, culture, religion, politics, administration, law, and so on.

Third, when water resources projects are developed, it is important to ensure that these projects achieve their intended objectives without causing deleterious environmental consequences, such as water logging, salinization, loss of wetlands, sedimentation of reservoirs, loss of biodiversity, etc.

Fourth, the combination of rising demand for water and increasing concern for environmental quality compels that water resources projects are planned, designed, executed and managed, keeping changing conditions in mind, especially climate change and social and economic changes.

Fifth, water resources projects are investment intensive and it is therefore important to take a stock of how the built projects have fared and the lessons that can be learnt so that future projects are even better. This requires an open and frank discussion among all sectors and stakeholders.

Sixth, we wanted to reinforce that water, environment, energy, and society constitute a continuum and water is central to this continuum. Water resources projects are therefore inherently interdisciplinary and must be so dealt with.

Seventh, a conference like this offers an opportunity to renew old friendships and make new ones, exchange ideas and experiences, develop collaborations, and enrich ourselves both socially and intellectually. We have much to learn from each other.

Now the question may be: Why India and why Bhopal? India has had a long tradition of excellence spanning several millennia in the construction of water resources projects. Because of her vast size, high climatic variability encompassing six seasons, extreme landscape variability from flat plains to the highest mountains in the world, and large river systems, India offers a rich natural laboratory for water resources investigations.

India is a vast country, full of contrasts. She is diverse yet harmonious, mysterious yet charming, old yet beautiful, ancient yet modern. Nowhere we can find mountains as high as the snow-capped Himalayas in the north, the confluence of three seas and large temples in the south, long and fine sand beaches in the east as well as architectural gems in the west. The entire country is dotted with unsurpassable monuments, temples, mosques, palaces, and forts and fortresses that offer a glimpse of India's past and present.

Bhopal is located in almost the center of India and is situated between Narmada River and Betwa River. It is a capital of Madhya Pradesh and has a rich, several century-long history. It is a fascinating amalgam of scenic beauty, old historic city, and modern urban planning. All things considered, the venue of the conference could not have been better.

We received an overwhelming response to our call for papers. The number of abstracts received exceeded 450. Each abstract was reviewed and about two thirds of them, deemed appropriate to the theme of the conference, were selected. This led to the submission of about 300 full-length papers. The subject matter of the papers was divided into more than 40 topics, encompassing virtually all major aspects of water and environment as well energy. Each topic comprised a number of contributed papers and in some cases state-of-the-art papers. These papers provided a natural blend to reflect a coherent body of knowledge on that topic.

The papers contained in this volume, "Water Resources Management," represent one part of the conference proceedings. The other parts are embodied in six companion volumes entitled, "Hydrologic Modelling," "Groundwater," "Environmental Pollution," "Water Quality Management," "Climate Change Impacts," and "Energy and Environment." Arrangement of contributions in these seven books was a natural consequence of the diversity of papers presented at the conference and the topics covered. These books can be treated almost independently, although significant interconnectedness exists among them.

This volume contains two parts. Part I deals with some aspects of irrigation, encompassing farm irrigation systems, landscape gardening, energy assessment for drip irrigation, and micro-sprinklers. Part II is on water resources planning and management. It discusses water crisis, challenges in river health management, water supply systems, salt water intrusion, lake management, water supply demand assessment, integrated water resources management, among other topics.

The book will be of interest to researchers and practitioners in the field of water resources, hydrology, environmental resources, agricultural engineering, watershed management, earth sciences, as well as those engaged in natural resources planning and management. Graduate students and those wishing to conduct further research in water and environment and their development and management may find the book to be of value.

WEES-16 attracted a large number of nationally and internationally well-known people who have long been at the forefront of environmental and water resources education, research, teaching, planning, development, management, and practice. It is hoped that long and productive personal associations and friendships will be developed as a result of this conference.

College Station, USA — Vijay P. Singh, Conference Chair
Bhopal, India — Shalini Yadav, Conference Organizing Secretary
Hazaribagh, India — Ram Narayan Yadava, Conference Co-Chair

Acknowledgements

We express our sincere gratitude to Shri Santosh Choubey, Chancellor, and Dr. V.K. Verma, Vice Chancellor, Board of Governing Body, and Board of Management of the AISECT University, Bhopal, India, for providing their continuous guidance and full organizational support in successfully organizing this international conference on Water, Environment, Energy and Society on the AISECT University campus in Bhopal, India.

We are also grateful to the Department of Biological and Agricultural Engineering, and Zachry Department of Civil Engineering, Texas A&M University, College Station, Texas, U.S.A., and International Centre of Excellence in Water Management (ICE WaRM), Australia, for their institutional cooperation and support in organizing the ICWEES-2016.

We wish to take this opportunity to express our sincere appreciation to all the members of the Local Organization Committee for helping with transportation, lodging, food, and a whole host of other logistics. We must express our appreciation to the Members of Advisory Committee, Members of the National and International Technical Committees for sharing their pearls of wisdom with us during the course of the Conference.

Numerous other people contributed to the conference in one way or another, and lack of space does not allow us to list all of them here. We are also immensely grateful to all the invited Keynote Speakers, and Directors/Heads of Institutions for supporting and permitting research scholars, scientists and faculty members from their organizations for delivering keynote lectures and participating in the conference, submitting and presenting technical papers. The success of the conference is the direct result of their collective efforts. The session chairmen and co-chairmen administered the sessions in a positive, constructive, and professional manner. We owe our deep gratitude to all of these individuals and their organizations.

We are thankful to Shri Amitabh Saxena, Pro-Vice Chancellor, Dr. Vijay Singh, Registrar, and Dr. Basant Singh, School of Engineering and Technology, AISECT University, who provided expertise that greatly helped with the conference organization. We are also thankful to all the Heads of other Schools, Faculty

Members and Staff of the AISECT University for the highly appreciable assistance in different organizing committees of the conference. We also express our sincere thanks to all the reviewers at national and international levels who reviewed and moderated the papers submitted to the conference. Their constructive evaluation and suggestions improved the manuscripts significantly.

Sponsors and Co-sponsors

The International Conference on Water, Environment, Energy and Society was Jointly organized by the AISECT University, Bhopal (MP), India and Texas A&M University, Texas, USA in association with ICE WaRM, Adelaide, Australia. It was partially supported by the International Atomic Energy Agency (IAEA), Vienna, Austria; AISECT University, Bhopal; M.P. Council of Science and Technology (MPCOST); Environmental Planning and Coordination Organization (EPCO), Government of Madhya Pradesh; National Bank for Agriculture and Rural Development (NABARD), Mumbai; Maulana Azad National Institute of Technology (MANIT), Bhopal; and National Thermal Power Corporation (NTPC), Noida, India. We are grateful to all these sponsors for their cooperation and providing partial financial support that led to the grand success to the ICWEES-2016.

Contents

About the Editors

Prof. Vijay P. Singh is University Distinguished Professor, Regents Professor, and the inaugural holder of the Caroline and William N. Lehrer Distinguished Chair in Water Engineering in the Department of Biological and Agricultural Engineering and Zachry Department of Civil Engineering at Texas A&M University. He received his B.S., M.S., Ph.D., and D.Sc. degrees in engineering. He is a registered professional engineer, a registered professional hydrologist, and an Honorary Diplomate of American Academy of Water Resources Engineers.

Professor Singh has extensively published the results of an extraordinary range of his scientific pursuits. He has published more than 900 journal articles; 25 textbooks; 60 edited reference books, including the massive Encyclopedia of Snow, Ice and Glaciers and Handbook of Applied Hydrology; 104 book chapters; 314 conference papers; and 72 technical reports in the areas of hydrology, ground water, hydraulics, irrigation engineering, environmental engineering, and water resources.

For his scientific contributions to the development and management of water resources and promoting the cause of their conservation and sustainable use, he has received more than 90 national and international awards and numerous honors, including the Arid Lands Hydraulic Engineering Award, Ven Te Chow Award, Richard R. Torrens Award, Norman Medal, and EWRI Lifetime Achievement Award, all given by American Society of Civil Engineers; Ray K. Linsley Award and Founder's Award, given by American Institute of Hydrology; Crystal Drop Award, given by International Water Resources Association; and Outstanding Distinguished Scientist Award given by Sigma Xi, among others. He has received three honorary doctorates. He is a Distinguished Member of ASCE, and a fellow of EWRI, AWRA, IWRS, ISAE, IASWC, and IE and holds membership in 16 additional professional associations. He is a fellow/member of 10 international science/engineering academies. He has served as President and Senior Vice President of the American Institute of Hydrology (AIH). Currently he is editor-in-chief of two book series and three journals and serves on editorial boards of 20 other journals.

Professor Singh has visited and delivered invited lectures in all most all parts of the world but just a sample: Switzerland, the Czech Republic, Hungary, Austria, India, Italy, France, England, China, Singapore, Brazil, and Australia.

Prof. Shalini Yadav is Professor and Head of the Department of Civil Engineering, AISECT University, Bhopal, India. Her research interests include solid and hazardous waste management, construction management, environmental quality and water resources. She has executed a variety of research projects/consultancy in Environmental and Water Science and Technology and has got rich experience in Planning, formulating, organizing, executing and management of R&D programs, seminars, and conferences at national and international levels. She has got to her credit guiding an appreciable number of M.Tech. and Ph.D. students. She has published more than 10 journal articles and 30 technical reports. Dr. Shalini has also visited and delivered invited lectures at different institutes/universities in India and abroad, such as Australia, South Korea, and Kenya.

Professor Shalini Yadav graduated with a B.Sc. in Science from the Bhopal University. She earned her M.Sc. in Applied Chemistry with a specialization in Environmental Science from Bhopal University and M.Tech. in Civil Engineering with a specialization in Environmental Engineering from Malaviya National Institute of Technology, Jaipur, India in 2000. Then she pursued the degree of Ph.D. in Civil Engineering from Rajiv Gandhi Technical University, Bhopal, India in 2011. Also, she is a recipient of national fellowships and awards. She is a reviewer for many international journals. She has been recognized for one and half decades of leadership in research, teaching, and service to the Environmental Engineering Profession.

Dr. Ram Narayan Yadava holds the position of Vice Chancellor of the AISECT University, Hazaribagh, Jharkhand. His research interests include solid mechanics, environmental quality and water resources, hydrologic modeling, environmental sciences and R&D planning and management. Yadava has executed a variety of research/consultancy projects in the area of water resources planning and management, environment, remote sensing, mathematical modeling, technology forecasting, etc.

He has got adequate experience in establishing institutes/organizations, planning, formulating, organizing, executing and management of R&D programs, seminars, symposia, conferences at national and international level. He has got to his credit guiding a number of M.Tech. and Ph.D. students in the area of mathematical sciences and Earth sciences. Dr. Yadava has visited and delivered invited lectures at different institutes/universities in India and abroad, such as USA, Canada, United Kingdom, Thailand, Germany, South Korea, Malaysia, Singapore, South Africa, Costa Rica, and Australia.

He earned an M.Sc. in Mathematics with a specialization in Special Functions and Relativity from Banaras Hindu University, India in 1970 and a Ph.D. in Mathematics with specialization in Fracture Mechanics from Indian Institute of Technology, Bombay, India, in 1975. Also, he is a recipient of Raman Research Fellowship and other awards. Dr. Yadava has been recognized for three and half decades of leadership in research and service to the hydrologic and water resources profession. Dr. Yadava's contribution to the state of the art has been significant in many different specialty areas, including water resources management, environmental sciences, irrigation science, soil and water conservation engineering, and mathematical modeling. He has published more than 90 journal articles; 4 textbooks; 7 edited reference books.

Part I
Irrigation

Identification of Farming Systems in Tribal Region of Zone IV-B of Rajasthan (India)

P. S. Rao and Hari Singh

Abstract The share of agriculture in gross domestic product has registered a steady decline from 36.4% in 1982–83 to 14.5% in 2013–14. Yet this sector continues to support more than half a billion people proving employment to 52% of the work force. It is also an important source of raw material and demand for many industrial products. Growth of agriculture over a period of time remained lower than the growth in non-agriculture sector. The gap began to widen since 1981–82 and more particularly since 1996–97, because of acceleration in the growth of industry and service sector. Survey on cropping system was carried out in tribal districts of Rajasthan. Using the stratified random sampling and probability proportion sampling, 450 farmers belonging to size groups, based on the size of holding were selected from five tehsils of tribal districts of Rajasthan. The secondary data has been taken from published records of state and central government. Data are interpreted as averages and percentages. The percentage of forest area to the total geographical area in Dungarpur and Banswara districts is more than double compared to forest area at the state level. It is evident that total cropped area in the state is 17,914,166 ha of which 55.76% (9,989,675 ha) kept under cereals and small millets, 24.84% (4,449,229 ha) under pulses, 18.82% (3,372,130 ha) under oilseeds crops and 0.58% (103,132 ha) under commercial crops. It is evident that of the total 577 lakh animals in the state, the population of goat is the highest (37.53%) followed by cattle (23.08%), buffalo (22.48%), and sheep (15.73%). In this study irrespective of the rain-fed and irrigated condition as well as location of the selected districts, four farming systems were observed. The study area is tribal dominating area where 50% tribal of the country are residing. An alternative farming system, which yields not only higher income but also utilizes family labor efficiency, needs to be evolved. Further, the system should help in restoration of ecological balance. The basic aim of integrated/sustainable farming system is to derive a set of resource development, management, and utilization practices that lead to a substantial and

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sustained increase in agricultural production. It is evident that out of 30 farmers, the maximum number of farmers (40%) adopted FS-II (Crop + Dairy) followed by FS-I (Crop + Vegetable) and FS-III (Crop + Dairy + Goat) and only 13.33% farmers followed FS-IV (Crop + Goat + Poultry). The highest cropping intensity was observed in FS-II (C+D), i.e., 94.44% followed by FS-I and FS-IV. The lowest cropping intensity was seen in FS-III (88.23%). In rain-fed area, cropping intensity was low due to non-availability of irrigation facilities and farmers were forced to take crops only in one season.

Keywords Socioeconomic · Farming systems · Tribal region · Cropping intensity

Introduction

Agriculture is mainstay of Indian Economy because of its high share in employment and livelihood creation not withstanding its reduced contribution to the notice GDP. The share of agriculture in gross domestic product has registered a steady decline from 36.4% in 1982–83 to 13.5% in 2012–13. Yet this sector continues to support more than half a billion people proving employment to 52% of the work force. It is also an important source of raw material and demand for many industrial products. Growth of agriculture over a period of time remained lower than the growth in non-agriculture sector. The gap began to widen since 1981–82 and more particularly since 1996–97, because of acceleration in the growth of industry and service sector. The study concluded by Poddar et al. (1995) in Karnataka has revealed that the optimization of resource use with the existing and improved technology led to cultivation of a few but more profitable crops in the new cropping patterns.

Rajasthan is the largest state of India with geographical area of 342.65 lakh hectares and occupies 10.41% land area of the country. About 46.30% area is under cultivation. Identification of efficient cropping systems with reference to productivity and sustainability has become imperative for different farming situations (Nanda et al. 1999). The whole state therefore, has been subdivides into 10 agro-climatic zones to cater the need-based and location-specific research demand. The zone IV-a&b Sub-humid Southern Plain and Aravali Hills covering Bhilwara, Udaipur, Rajsamand, Pratapgarh, Dungarpur, Banswara, and Sirohi district where maize, wheat, gram, paddy, and urad are the major crops grown in this area. This area is tribal dominating area where 50% tribal of the country are residing. An alternative farming system, which yields not only higher income but also utilizes family labor efficiency, needs to be evolved. Further, the system should help in restoration of ecological balance. The basic aim of integrated/sustainable farming system is to derive a set of resource development, management, and utilization practices that lead to a substantial and sustained increase in agricultural production. Since farming systems differ in different situations such studies should be location-specific (Singh 1998). Looking to the above factors, this study has been conducted with the objectives (i) to examine the resource characterization, (ii) to study the cropping system of the tribals, and (iii) analyze the farming system along with income and employment pattern in the study area. Keeping the above objectives in mind this study has been conducted with the following methodology.

Methodology

Survey on cropping system was carried out in two districts out of four districts of tribal abundance population (Banswara and Dungarpur) of Rajasthan, which falls under Zone IV-b (Humid Southern Plain). Stratified random sampling technique was used for selection of Tehsil, and villages. While farmers have been selected through probability proportion sampling, a total of 450 farmers were ultimately selected, based on the size of operational holding. The size of holding so selected was, small (1–2 ha), medium (2–4 ha), and large (above 4 ha). Selected farmers were from five tehsils of two tribal districts of Rajasthan of Zone IV-b (Humid Southern Plain). Two tehsils from Dungarpur and three tehsils from Banswara have been selected. From each tehsil, 15 farmers from rain-fed and 15 farmers from irrigated area in each category of small, medium, and large size holding have been selected. In this way, 45 farmers in rain-fed and 45 farmers in irrigated area have been selected from each selected tehsil. The data on socioeconomic parameters, like existing cropping system, and income and employment pattern were obtained in pre-tested schedule. The survey has been conducted by way of the questionnaires. The secondary data has been taken from published records of state and central government. Data were analyzed and interpreted by using averages and percentages.

Results

Land Utilization Pattern of the Study Area—Agriculture is the main occupation in both the selected districts. Land utilization pattern of Dungarpur and Banswara district (tribal) as well as of the Rajasthan State is presented in Table 1. Out of 343 lakh hectares geographical area of Rajasthan state, Dungarpur district contributed 3.85 lakh hectares whereas Banswara district contributed 4.54 lakh hectares. The percentage of forest area to the total geographical area in both the districts is more than double compared to forest area at the state average. The forest area of Dungarpur is, 16.00% while it is 20.12% in Banswara district compared to 8.02% of the state average.

Data further shows that area not available for cultivation is high in both the districts, Dungarpur (24.10%) and 13.80% in Banswara due to barren land area; which is again greater than state average (12.46%). Uncultivated land is more in Dungarpur district (14.68%) as compared to Banswara district (8.69%) which is due

Table 1 Land utilization pattern of the study area (2011–12) (area in ha)

S. No.	Particulars	Dungarpur district	Banswara district	Rajasthan state
A	Total geographical area	385,593 (100.00)	453,612 (100.00)	34,267,252 (100.00)
1	Area under forest	62,204 (16.13)	91,250 (20.12)	2,746,686 (8.02)
2	Land not available for cultivation	92,943 (24.10)	62,589 (13.80)	4,271,340 (12.46)
	(i) Non-agricultural uses	22,970 (5.96)	11,017 (2.43)	1,884,055 (5.50)
	(ii) Barren	69,973 (18.15)	15,172 (11.37)	2,387,285 (6.97)
3	Other uncultivated land	56,589 (14.68)	39,415 (8.69)	5,883,545 (17.18)
	(i) Cultivated waste	20,811 (5.40)	24,789 (5.46)	4,168,681 (12.17)
	(ii) Permanent pasture	34,539 (8.96)	11,509 (2.54)	1,693,790 (4.94)
	(iii) Trees and groove	1239 (0.03)	117 (0.03)	21,074 (0.001)
4	Fallow land	39,387 (10.21)	36,521 (8.05)	3,331,274 (9.72)
	(a) Current fallow	8373 (2.17)	4558 (1.00)	1,476,694 (4.31)
	(b) Other fallow	31,014 (8.04)	21,963 (4.84)	1,854,580 (5.41)
5	Net sown area	134,470 (34.87)	226,812 (50.00)	18,034,407 (52.63)
6	Area sown more than once	65,417 (8.04)	109,903 (24.23)	6,470,962 (18.88)
7	Total cropped area	199,887 (34.87)	336,742 (74.24)	24,505,369 (71.51)
B	Cropping intensity (%)	149	148	136
C	Irrigated area as percentage of net sown area (%)	34.26	44.19	39.49
D	Total net irrigated area	46,077 (100.00)	100,228 (100.00)	7,121,575 (100.00)
	(a) Area under canal irrigation	9295 (20.17)	59,019 (58.88)	1,843,797 (25.89)
	(b) Tanks	2489 (5.40)	5005 (4.99)	68,785 (9.65)
	(c) Wells and Tubewells	31,438 (68.22)	17,999 (17.96)	5,111,105 (71.77)
	(d) Others	2855 (6.20)	18,205 (18.16)	97,888 (1.87)

Source Statistical abstract, 2012. Directorate of economics and statistics Rajasthan, Jaipur (figures in parentheses denotes percentage to respective totals) to the permanent pasture, trees, and groove while it is 17.18% at state level. As far as fallow land is concerned Dungarpur districts have more area under fallow land (10.21%) and in Banswara it is (8.05%) as compared to state average (9.72%). Cropping intensity in Dungarpur (149%) and Banswara (148%) district is more than the state average (136%). Data show that net sown area in Dungarpur was (34.87%) which is less than both Banswara (50.00%) and the state (52.63%) as a whole. At the state level, area under canal and well irrigation accounted for 25.89 and 71.71% respectively. The irrigated area in Banswara district under canal (58.88%) and in Dungarpur under well and well tube (68.22%) was found highest.

It can be concluded that an alternative farming system should be adopted by the farmers, which yields not only higher income but also utilizes family labor efficiency. Further, the system should help in restoration of ecological balance. It is evident that out of 450 farmers, the maximum number of farmers (40%) adopted crop production along with dairy farming so that they will be mutually beneficial to each other where by-product of both the enterprises can be fully utilized by each other. Farming System-II (Crop + Dairy).

Area Under Various Crops in Study Area

There are number of crops grown in Rajasthan state as well as in the selected districts. The area put under different crops in Dungarpur and Banswara tribal districts and in the state is presented in Table 2.

It is evident from the table that total cropped area in the state is 17,914,166 ha of which 55.76% (9,989,675 ha) kept under cereals and small millets, 24.84% (4,449,229 ha) under pulses, 18.82% (3,372,130 ha) under oilseeds crops and 0.58% (103,132 ha) under commercial crops. In both the selected districts maize, wheat, gram, other kharif pulses and groundnut are the major important crops which yield a major share of fodder for dairy animals which support the farmers to withstand at the time of crop failure in adverse condition and survive on dairy through diversification.

Livestock Population in the Study Area

Almost all types of pet animals are reared in Rajasthan. The livestock population in the tribal districts and Rajasthan state is presented in Table 3. It is evident from the table that of the total 577 lakh animals in the state, the population of goat is the highest (37.53%) followed by cattle (23.08%), buffalo (22.48%) and sheep (15.73%).

Table 2 Area under different crops in the study area (2011–12) (area in ha)

S. No.	Crops	Banswara district	Dungarpur district	Rajasthan state
A	*Cereals*			
	Bajra	101 (0.00)	124 (0.0006)	5,027,993 (28.07)
	Sorghum	383 (0.12)	549 (0.003)	553,796 (3.09)
	Maize	145,482 (46.47)	82,205 (42.86)	1,045,591 (5.84)
	Wheat	87,177 (27.85)	45,085 (23.50)	2,935,341 (16.39)
	Barley	1,023 (0.33)	1100 (0.57)	278,016 (1.55)
	Rice	28,542 (9.12)	22,031 (11.49)	134,337 (0.70)
	Small millets	4,128 (1.32)	6,130 (3.20)	14,601 (0.01)
	Sub-total	266,836 (85.23)	157,224 (81.97)	9,989,675 (55.76)
B	*Pulses*			
	Gram	13,719 (4.38)	14,971 (7.80)	1,433,954 (8.00)
	Other rabi pulses	2,251 (0.72)	1,524 (0.70)	43,760 (0.24)
	Other Kharif pulses	11,587 (3.70)	12,890 (6.72)	2,952,406 (16.48)
	Tur/Arhar	5,632 (1.80)	1,854 (0.97)	19,115 (0.11)
	Sub-total	33,189 (10.60)	31,239 (16.29)	4,449,229 (24.84)
C	*Oil seeds*			
	Sesamum	634 (0.20)	1,453 (0.76)	512,766 (2.86)
	Rape seed and mustard	99 (0.03)	760 (0.40)	2,441,254 (13.63)
	Groundnut	205 (0.07)	41 (0.00)	418,110 (2.33)
	Sub-total	938 (0.30)	2,254 (1.18)	3,372,130 (18.82)
D	*Commercial crops*			
	Sugarcane	146 (0.05)	64 (0.00)	6415 (0.04)
	Cotton	11,954 (3.82)	1,033 (0.54)	96,717 (0.54)
	Sub-total	12,100 (3.87)	1,097 (0.97)	103,132 (0.58)
E	Total cropped area	31,363 (100.00)	191,814 (100.00)	17,914,166 (100.00)

Source Statistical abstract, 2012. Directorate of economics and statistics Rajasthan, Jaipur (figures in parentheses denotes percentage to total cropped area)

The share of livestock population in Banswara and Dungarpur districts in the total livestock population of Rajasthan state is 2.42 and 1.89%, respectively. The percentage of cattle population was the highest (42.89%) in Banswara district while goat population was found highest (38.24%) in Dungarpur while it is 36.17% in Banswara. The buffalo population has also shown significant presence (above 20%) in livestock population of Dungarpur and Banswara districts. Total state poultry birds population was 80.24 lakhs of which 2.22 and 3.35% were found in Banswara

Table 3 Livestock population in the study area (2007) (number)

S. No.	Livestock	Banswara district	Dungarpur district	Rajasthan state
A	Animal husbandry			
	Goat	504,758 (36.17)	416,729 (38.24)	21,665,939 (37.53)
	Sheep	7,207 (0.52)	62,652 (5.75)	9,079,702 (15.73)
	Buffalo	282,438 (20.24)	232,133 (21.30)	12,976,095 (22.48)
	Cattle	598,453 (42.89)	375,023 (34.42)	13,324,462 (23.08)
	Pig	125 (0.2)	38 (0.00)	237,674 (0.04)
	Camel	558 (0.04)	1,672 (0.15)	325,713 (0.56)
	Donkey	1,713 (0.12)	1,214 (0.11)	81,468 (0.14)
	Horse	165 (0.01)	138 (0.01)	37,776 (0.07)
	Total livestock	1,395,418 (100.00)	1,089,600 (100.00)	57,732,204 (100.00)
B	Poultry	268,707 (19.26)	177,807 (16.32)	8,024,424 (13.90)

Source Statistical abstract, 2012. Directorate of economics and statistics Rajasthan, Jaipur (figures in the parentheses are percentage to the column total in livestock and row total in poultry)

and Dungarpur, respectively. Thus, on the basis of population of milking animals, farming system of crop production with dairy animals predominantly existed to maximize the farm income in the tribal area of southern Rajasthan.

Farming Systems

There are number of farming systems that existed in the study area. Farming system is a combination of crops, vegetables, orchards, dairy enterprise, and poultry to maximize the farm income. In this study, irrespective of the rain-fed and irrigated condition as well as location of the selected districts, four farming systems were observed.

$$\text{FS-I} : \text{Crops} + \text{Vegetable}(\text{C} + \text{V})$$
$$\text{FS-II} : \text{Crops} + \text{Dairy}(\text{C} + \text{D})$$
$$\text{FS-III} : \text{Crops} + \text{Dairy} + \text{Goat}(\text{C} + \text{D} + \text{G})$$
$$\text{FS-IV} : \text{Crops} + \text{Goat} + \text{Poultry} + \text{Orchard}(\text{C} + \text{G} + \text{Po} + \text{O})$$

The farming systems that existed in Dungarpur and Banswara districts in rain-fed and irrigated conditions were studied separately. A condition in which the crops depend on the rainfall and rainfall is below 500 mm per annum as well as the irrigation is not assured was considered as rain-fed condition. The irrigated condition was one where assured irrigation facilities for growing the crops exist and crops do not depend on rainfall. The discussion on various aspects of farming systems in rain-fed and irrigated condition is on the average per farm.

Farming Systems in Dungarpur District

The farming system existing in rain-fed and irrigated conditions was studied and discussed under the heads of number of farmers, cropping intensity, cropping pattern, and non-crop enterprises in different farming systems. The Sagwadra tehsil was selected as rainfed and Aspur was selected as irrigated tehsil.

Rain-Fed Condition

Farming system in rain-fed area of Dungarpur district is presented in Table 4. It is evident from the table that in this area, crops were grown only in kharif season and dairy, goat and poultry are also taken up by the farmers along with crops and vegetables. It is evident from Table 4, that out of 30 farmers, the maximum number of farmers (40%) adopted FS-II (Crop + Dairy) followed by FS-I (Crop + Vegetable) 23.33%, FS-III (Crop + Dairy + Goat) and only 13.33% farmers followed FS-IV (Crop + Goat + Poultry).

The cropping intensity ranged from 94.34 to 98.00%. The highest cropping intensity was observed in FS-I whereas lowest cropping intensity was found in FS-IV. There was a very little variation in the cropping intensity among four farming systems because of rain-fed condition.

Maize and soybean were prominent crops grown in all the four farming systems, black gram in three farming systems while green gram and vegetables had sown their presence only in one farming system. In FS-I, the average total cropped area was 1.14 ha of which kharif crops were put under 1.04 ha (91.2%) and only 0.1 ha was kept under vegetables. In FS-II, the crops were same as grown in FS-I. Out of the gross cropped area of 1.17 ha, soybean was grown in the maximum area (0.52 ha) followed by maize (0.45 ha) and black gram (0.20 ha). Similarly in FS-III with the gross cropped area was 0.60 ha, the crops grown were maize (0.30 ha), soybean (0.20 ha), and black gram (0.10 ha), while in FS-IV gross cropped area was 0.50 ha and black gram crop which found a first place in all three farming systems was replaced by green gram in this farming system and other two crops, i.e., maize and soybean remained the same. The area under crops in all the four systems was 3.41 ha in which FS-II contributed the maximum area (34.31%) followed by FS-I (33.43%). Thus, it can be concluded that maize and soybean were the important crops in all the farming systems and vegetables got its place only in FS-I.

Non-crop enterprises such as dairy cattle, goat, and poultry were found only in three farming systems, i.e., FS-II, FS-III, and FS-IV and in FS-I non-crop enterprises have not occupied any place. Thus, it can be concluded that non-crop enterprises has shown their existence only in three systems. Dairy enterprises (FS-II and FS-III) and goat enterprises (FS-III and FS-IV) were taken up in two farming

Table 4 Existing farming systems in rain-fed condition of Dungarpur district (per farm)

Farming system	No. of farmers	Gross cropped area (ha)	Cultivated area (ha)	Cropping intensity (%)	Crops		Vegetable		Dairy cattle (No)	Goat (No)	Poultry (No)
					Name	Area (ha)	Name	Area (ha)			
FS-I (C+V)	7 (23.33)	1.14 (33.43)	1.16	98.28	Maize	0.38	Okra	0.05	–	–	–
					Soybean	0.34					
					Black gram	0.32	Bottle gourd	0.05			
FS-II (C+D)	12 (40.00)	1.17 (34.31)	1.20	97.50	Maize	0.45	–	–	2.08	–	–
					Soybean	0.52					
					Black gram	0.20					
FS-III (C+D+G)	7 (23.33)	0.60 (17.60)	0.62	96.77	Maize	0.30	–	–	2.40	8.50	–
					Soybean	0.20					
					Black gram	0.10					
FS-IV (C+G+Po)	4 (13.33)	0.50 (14.66)	0.53	94.34	Maize	0.20	–	–	–	7.04	52.85
					Greengram	0.10					
					Soybean	0.10					
					Fallow land	0.10					
Total	30 (100)	3.41 (100)	3.51	96.72	–	3.31	–	0.10	4.48	15.54	52.85

C Crop, *D* dairy, *Po* poultry, *G* goat (figures in parentheses are percentage of column total)

Table 5 Existing farming systems in irrigated condition of Dungarpur district (per farm)

Farming system	No. of farmers	Gross cropped area (ha)	Cultivated area (ha)	Cropping intensity (%)	Crops		Vegetable		Dairy cattle (No)	Goat (No)	Poultry (No)
					Name	Area (ha)	Name	Area (ha)			
FS-I (C+V)	6 (20.23)	2.24 (26.23)	1.16	193.10	Maize	0.45	Tomato	0.22	–	–	–
					Cotton	0.15	Okra	0.30			
					Wheat	0.65	Bo.gourd	017			
					Mustard	0.29	Bi.gourd	0.01			
FS-II (C+D)	14 (46.67)	2.30 (26.93)	1.20	191.67	Maize	0.80			3.50	–	–
					Soybean	0.20					
					Cotton	0.20					
					Wheat	0.95					
					Barley	0.05					
					Mustard	0.10					
FS-III (C+D +G)	3 (10.00)	2.15 (25.18)	1.10	195.45	Maize	0.65			2.60	8.50	–
					Soybean	0.35					
					Black gram	0.25					
					Wheat	0.70					
					Mustard	0.20					
FS-IV (C+G +Po)	4 (23.33)	1.85 (21.66)	0.98	188.77	Maize	0.50			–	7.04	52.85
					Greengram	0.20					
					Cotton	0.25					
					Soybean	0.20					
					Wheat	0.55					
					Mustard	0.15					
Total	30 (100)	8.54 (100)	4.44	192.25		7.84		0.70	6.10	120	37.55

C Crop, *D* dairy, *Po* poultry, *G* goat (figures in parentheses are percentage of column total) systems while poultry birds existed only in one farming system (FS-IV). Ram Rao et al. (2005) also identified crop + livestock integrated farming system in rain-fed area of Chhattisgarh in Central India. Similar results were also reported by Nayak (2003).

The various farming systems prevalent in irrigated area of Dungarpur district is presented in Table 5. Results showed that maximum number (46.67%) of farmers adopted FS-II (C+D) followed by FS-IV (23.23), FS-I (20%), and the lowest in FS-III (10.00%).

Data revealed that cropping intensity varied from 188.77 to 195.45%. The highest cropping intensity was observed in FS-III (195.45%) followed by FS-I (193.10%), FS-II (191.67%), and the lowest in FS-IV (188.77%). Under irrigated condition, the cropping intensity in all the farming systems was more than 100 because farmers take crops and vegetables in both the seasons due to availability of irrigation facilities.

The total cropped area in FS-I, FS-II, FS-III, and FS-IV were 2.24, 2.30, 2.15, and 1.85 ha, respectively. Thus, in all the farming systems, there was a good scope to cultivate the crops in both the seasons because of assured irrigation facility. It is observed from Table 5, that non-crop enterprises were found only in three systems, i.e., FS-II, FS-III, and FS-IV. In FS-II, the average number of dairy cattle was 3.50 where as it was 2.60 in FS-III. The average number of goats was 16.00 in FS-III whereas in FS-IV in addition to 11.50 average number of goats, 120 fruit plants in the orchard were also maintained. Thus, it can be concluded that non-crop enterprises showed their presence in three farming systems. Dairy cattle were found in two systems (FS-II and FS-III), goat was also found in two systems (i.e., FS-III and FS-IV), while orchard was found only in one farming system, i.e., FS-IV. Similar findings were found by Baishya et al. (2007), both in irrigated and rain-fed farming system in Karupt and Borpeta districts of Assam. The main components of the farming system in these districts were crops, dairy, goat, and piggery.

Farming Systems in Banswara District

Farming systems in Banswara district were studied in both, i.e., rain-fed and irrigated condition. The selected rain-fed tehsil was Kushalgarh, Gaddi, and Banswara.

Rain-Fed Condition

In rain-fed condition farmers of Banswara were taking only crops and onion nursery in kharif season while in rabi season land were kept fallow due to unavailability of irrigation facilities. Data revealed that maximum number of farmers (43.33%) falls in FS-II (C+D) and minimum number of farmers (13.33%) adopted FS-I (C+ON) as

Table 6 Existing farming systems in rain-fed condition of Banswara district (per farm)

Farming system	No. of farmer	Gross cropped area (ha)	Cultivated area (ha)	C.I. (%)	Crops		Onion nursery		Dairy cattle (No)	Goat (No)	Poultry (No)
					Name	Area (ha)	Name	Area (ha)			
FS-I (C+V)	4 (13.33)	0.58 (25.00)	0.62	93.55	Maize	0.25	Onion Nursery	0.08	–	–	–
					Soybean	0.10					
					Paddy	0.15					
FS-II (C+D)	13 (43.33)	0.85 (36.63)	0.90	94.44	Maize	0.45	–	–	3.06	–	–
					Soybean	0.10					
					Paddy	0.15					
FS-III (C+D +G)	7 (23.33)	0.45 (19.39)	0.51	88.23	Maize	0.20	–	–	3.00	17.00	–
					Soybean	0.15					
					Black gram	0.10					
FS-IV (C +Po)	6 (20.00)	0.44 (18.96)	0.48	91.66	Maize	0.24	–	–	–	–	55.75
					Paddy	0.20					
Total	30 (100.0)	2.32 (100.0)	2.51	91.97	–	2.24	–	0.08	6.06	17.00	55.75

C Crop, *V* vegetable, *D* dairy, *Po* poultry, *G* goat (figures in parenthesis is percentage of column total)