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Regional scale cropping systems management options in Telangana using WorldClim data

MANORANJAN KUMAR*, K.S. REDDY and K. SAMMI REDDY

Division of Resource Management, ICAR-Central Research Institute for Dryland Agriculture, Santosh Nagar, Hyderabad, Telangana – 500059

**Corresponding author: manocrida75@gmail.com*

ABSTARCT

The present study evaluates the existing district-wise cropping system of *Kharif* and *Rabi* season prevailing in Telangana State of India. In *kharif* season, it was observed that all districts of the states are water surplus and whereas during *Rabi* season all districts become water deficit. In order to enhance the agricultural production and agricultural based rural economy, alternate cropping system were suggested. Due consideration was given to the existing water resource and farming practices prevailing in the respective district. Re-appropriation of area under various crops was suggested for two scenarios namely, 'A' and 'B', aimed for reduction in crop water requirement by 10 % and 20 %, respectively. In scenario 'A', it was suggested to reduce the area under transplanted paddy and ground nut by half and 40% respectively,in *kharif* season and substantial enhancement in the area under redgram. For *rabi* season the area under transplanted paddy could be reduced to half for scope to double the area under oilseed. The scenario 'B' however is feasible in 3 districts, suggests restricting the area under groundnut to comprehensive increase in pulse area. For *rabi* in scenario 'B', it is recommended to further reduce the area under oilseed, paddy and other crops allows more crop diversity including millets, sorghum and caster. The economic analysis suggested that the alternate scenario has the potential to significantly improve the benefit cost ratio apart from enhancement in water productivity.

Key words: Dryland farming, water management, crop diversity, rainfed agriculture, composite crop coefficient

Rainfed agriculture in India practiced in 76 mHa area which contributes 44% to the national food basket providing food to 40% population (Sharma, 2011) and supports 80 and 60% of horticulture and livestock respectively. The agricultural production system under rainfed conditions, primarily depending on climatic parameters that includes rainfall, temperature, humidity, solar radiation etc. among which rainfall is considered as the most critical input resources. The significant variation in rainfall over space and time coupled with erratic distribution with higher coefficient of variation adversely affects the sustainability of rainfed agricultural production system (Cooper *et al.,* 2008). The deleterious effect of climate change on agriculture makes farming more vulnerable. Rainwater management assumes major role in achieving resilience in agriculture and thus sustainability in food production (Bastakoti *et al*., 2016). For effective rainwater management, crop planning based on water budget is most important (Singh *et al.,* 2019).

Rainfall variation in South-West monsoon – *kharif* season particularly, causing instability in *kharif* crop production. Two third of the geographical area in India, is prone to drought of varying degrees to the extent of acute drought due to variation in rainfall distribution (Gupta *et al*. 2011). The increased frequency on extreme events of flood and drought has the potential to reduce more than 20% of crop net revenue. CRIDA, 2013 develop Vulnerability Index (Rama Rao *et al.,* 2013) considering comprehensive indicators ranging from climate, soil, crop and socio-economics.

In rainfed agriculture, water is usually a limiting factor due to climatic conditions and so the yield potential is significantly low. Srinivasarao *et al.*(2015) estimated the potential yield and yield gap of major rainfed crops and cited the mid-season drought and weather aberrations are major reason. Paydar and Qureshi (2012) suggested adjustable mechanism for rainwater management to address the uncertain and dynamic sets of climate change impact and socio-economic conditions. This include facilitating stakeholders with quantitative and qualitative information on the uncertainty characteristics of management verticals derived from climate change impact forecasts (Brekke *et al.,* 2004, Rao and Punia, 2011; Ruane *et al.,* 2013). It is important to adopt appropriate planning and mitigation measures to address the adverse impact of climate change (Raje and Mujumdar, 2010) and these impacts must be considered when making long-term planning and management decisions (Kadaliya *et al.,* 2015). Pramod *et al.,* 2018 projected the irrigation water requirement for the wheat growing district based on NorESM1-M model of CMIP5 combined with RCP4.5.

South Central India facing an acute water crisis leading to fall in groundwater critically (Reddy *et al.,* 2015). The demand-based water management systems focus to reduce the gaps between supplies and demands and thus the water use efficiency increases (Raoand Rajput, 2009). Water requirement of various crops in the cropping system is an important aspect in optimizing water resources in enhancing water productivity and tradeoff between total production and productivity. The cropping system that includes rainfed crops may be more efficient in view of water productivity but may result in lower production. The sustainable cropping system is utmost important to assess the adaptive capabilities of water resources development under paradigm shift in climate conditions as well as socio-economic.

In view of above, this study was undertaken with the objective to evaluate the existing crops and cropping system with respect to water use efficiency and suggest change in cropping system to further enhance the rain water productivity as well rural economy and livelihood.

MATERIALS AND METHODS

Study area

The state of Telangana is bounded by 17°07'Nand 79°12'Eand spread over 11.2 mha area and mostly fall into deccan plateau agro-ecosystem which is hot-moist semi-arid. The regionreceives 80% and 20% of annual rainfall during *Kharif* and *Rabi,*respectively resulting into 120% cropping intensity Broadly. Telangana is divided into two agro-ecological regions namely, Northern Telangana zone and Southern Telangana zone. The typical characteristics of these regions are provided in table 1.

Data

The monthly average rainfall data layer of both the seasons was obtained from WorldClim global climate data (Hijmans *et al*., 2005) for 1950-2000 periods. These data are extensively used in several studies on spatial modeling particularly in investigating impact of Clean Development Mechanism – Afforestation/Reforestation (CDM-AR) on different ecological parameters (Trabucco *et al.,* 2008; Zomer *et al.,* 2007; 2008, Rodrigo *et al.,* 2010; Jones and Thronton, 2012; Donink *et al.,* 2014; Yagini and Panos, 2016). Global-PET, a grid based spatially distributed potential evapotranspiraton (Hargreaves *et al.,* 1985) was also obtained as open source data for year 2014-15. The district-wise crop data and other agricultural information for year 2014-15 were collected from the various publications on agricultural statistics from different government departments. However, the relevant complete set of data including exclusive water resources data for Nizamabad district was not available and thus is not included in the study.

Methodology

Three major crops under irrigated and rainfed conditions were identified for *kharif* and *Rabi* for each district. All data were converged in the GIS environment (ArcInfo 9.3) to perform climatic water balance. The respective district and state shapefile were superimposed to the rainfall and PET data and accordingly data was extracted. These extracted data were then interacted using mathematical operator to determine the deficit and surplus district based on seasonal rainfall and PET.

Computation of composite crop coefficient, K

The composite crop coefficients were computed to address the issue of different crop coefficient of crops in the season. This was done to bring a unique crop coefficient values to simplify the analysis for water use efficiency. The computation was done in such a way that, the crop under more area has more bias in composite crop coefficient. This was computed using the following formula for weighted mean.

$$K = \frac{\sum Kc_i \times A_i}{\sum A_i} \qquad \ldots(1)$$

Where, K is composite crop coefficient, Kc_i is crop coefficient of crop i, A_i is area under crop

The average seasonal crop coefficient, Kc values, adopted from FAO-56 (Allen *et al.,* 1998). Cropping system having composite crop coefficient of 0.65 is considered as the most water efficient cropping system.

It is hypothesized that the improvement in the rainwater water use efficiency could be achieved by reallocating the areas under different crop by reverse

Table 1: Agro-ecological characteristics of different regions of Telangana

Agro-ecological region	Districts	Climate	Prevailing Soil type	Annual rainfall (mm)	Agricultural Land use	
					Net sown area (,000 ha)	Cropping intensity (%)
North Telangana zone	Adilabad Khammam Karimnagar Warangal Nizamabad	Semi-arid	Black soil (56.0%) Red soil (28.3 %)	800-1050	2455	125.7
Southern Telangana zone	Mahbubnagar Medak Nalgonda Rangareddy	Semi-arid	Red soil (46.1 %) Sandy loam (24.1 %)	700-840	1818	112.7

Table 2: Composite crop coefficient, Ks, computed for existing, scenario A and scenario B

District	Composite crop coefficient, K, *kharif*				Composite crop coefficient, K, *rabi*			
	Area	Existing	Scenario A	Scenario B	Area	Existing	Scenario A	Scenario B
Adilabad	485	0.83	0.74	0.66	77.9	0.65	0.58*	0.52*
Karimnagar	336.6	0.91	0.82	0.72	131.4	0.93	0.83	0.74
Khammam	335.5	0.91	0.82	0.73	58.8	0.89	0.80	0.71
Mahbubnagar	499	0.80	0.72	0.64*	396	0.80	0.72	0.64*
Medak	269	0.82	0.74	0.66	115.2	0.75	0.68	0.60*
Nalgonda	390	0.85	0.77	0.68	164.3	0.97	0.87	0.78
Rangareddy	84.7	0.79	0.71	0.63*	33	0.79	0.71	0.64*
Warangal	341	0.89	0.80	0.71	46	0.72	0.65	0.58*

* Corresponding scenario is not feasible

calculation using the reduction the composite K. Two scenarios i.e. A and B are considered in which composite K is reduced by 10% and 20%, respectively but not less than 0.65. The computed composite crop coefficient for different scenario is given in Table 2. Accordingly, ETc calculated for K and superimposed with seasonal rainfall to identify surplus and deficit district for different scenario. These resultant data thus obtained was corroborated with the existing water resource available in the district (Table 3) and after considering these, alternate cropping system were suggested.

Economic analysis

Economic analysis was performed for three parameters namely, cost of cultivation, return and benefit:cost (B:C) ratio for existing cropping system as well as for scenario A and B. These 3 economic parameters were computed for all 8 districts for *Kharif* as well as *Rabi* season. For computing various parameters, the prevailing rate of various agricultural input and output for year 2018-19 were taken in to the consideration. The cost of cultivation was computed using A2+FL formula as suggested by commission for agricultural cost and price (CACP). A2 includes all the paid-up actual cost in purchase of all inputs including seed, fertilizers, chemicals, hiring labour, machinery and services as well as leased-in land. FL components includes the family labour in monetary terms. Returns were computed from the prevailing MSP of the crops. The B:C ratio was determinized using the following equation

$$B:C = \frac{\sum A_i \times R_i}{\sum A_i X C_i} \quad \ldots(2)$$

Where, B:C is B:C ratio, A_i, R_i and C_i are area, return (Rsha^{-1}) and cost (Rsha^{-1}) for i^{th} crop, respectively.

Table 3: District wise existing water resources and utilization in agriculture (Telangana)

District	Annual Rainfall	Net sown area (,000 ha)[1]	Area irrigated[2] Ground water resources	Surface water resources	Cropping intensity (%)[3]
Adilabad	1053	552	86.6	27.5	115
Karimnagar	920	454	314.2	61.1	128
Khammam	1059	382	101.8	68.9	109
Mahbubnagar	692	836	196.3	30.8	108
Medak	1001	457	211.6	19.6	116
Nalgonda	753	571	268.8	53.1	117
Rangareddy	838	209	74.9	5.8	111
Warangal	1059	492	276.5	84.2	126

[1] Agricultural Statistics at a Glance 2015-16, Directorate of Economics and Statistics, Government of Telangana.

[2] 5th minor irrigation census, reference year 2013-14.

[3] Derived from the data presented in Agricultural Statistics at a Glance 2015-16, Directorate of Economics and Statistics, Government of Telangana.

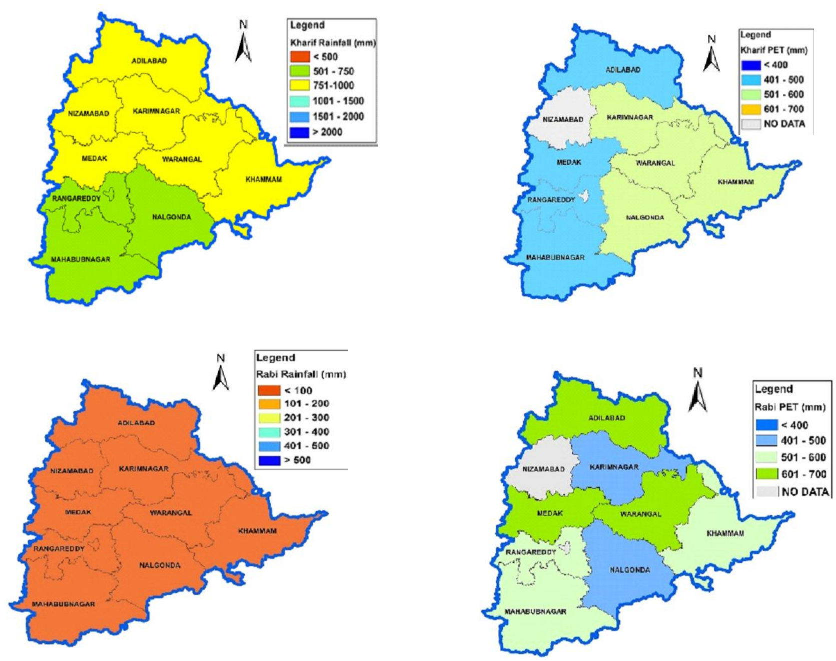

Fig. 1: District wise rainfall and PET during *kharif* and *rabi*

RESULTS AND DISCUSSION

Rainfall and evapotranspiration

Southern districts receive less than 500 mm rainfall in *kharif* season whereas PET requirement normally exceeds causing rainfed agriculture and sustenance farming in these areas. Though irrigated agriculture also practiced in few pockets in these areas, nevertheless it based on groundwater over-exploitation. The northern part of the region experiences rainwater surplus over PET providing scope to cultivate water intensive crop during *kharif* with existing water resources available.

In general, all the area receives meager rainfall i.e. less than 100 mm during *rabi season.* Despite variation in rainfall and PET, water deficit conditions prevailing in all districts in *rabi* season. These situations resulted into limited farming activities during *rabi* season and lead to exploitation of ground water in rainfed and irrigated area respectively. The district wise variation in PET and rainfall are presented in Fig. 1.

Table 4 : Existing and proposed cropping pattern – *Kharif* season (Area in ,000 ha)

District	Primary crop				Secondary crop				Tertiary crop			
	Rainfed	Area	Irrigated	Area	Rainfed	Area	Irrigated	Area	Rainfed	Area	Irrigated	Area
Existing												
Adilabad	Cotton	292	Paddy	20	Soyabean	120	…	0	Redgram	53	…	0
Karimnagar	Cotton	62	Paddy	126.6	…	0	Maize	106	…	0	Cotton	42
Khammam	Cotton	98.5	Paddy	150	Maize	16	Maize	30	Mung	21	Cotton	20
Mahbubnagar	Paddy	181	Castor	139	…	0	Maize	113	…	0	Redgram	66
Medak	Paddy	62	Maize	103	Sugarcane	28	Mung	48	Sunflower	2	Jowar	26
Nalgonda	Paddy	163	Cotton	106.2	Mung	43.9	Castor	39.4	…	0	Redgram	37.5
Rangareddy	Paddy	18	Redgram	29.7	…	0	Maize	20.8	…	0	Cotton	16.2
Warangal	Paddy	107	Cotton	95	Cotton	63	Maize	41	Chillies	14	Redgram	21
Proposed for Scenario A												
Adilabad	Cotton	150	Paddy	10	Soyabean	160	…	0	Redgram	165	…	0
Karimnagar	Cotton	38	Paddy	5	…	0	Maize	262	…	0	Cotton	32
Khammam	Cotton	79	Paddy	30	Maize	86	Maize	80	Mung	41	Cotton	20
Mahbubnagar	Paddy	81	Castor	139	…	0	Maize	113	…	0	Redgram	166
Medak	Paddy	32	Maize	103	Sugarcane	8	Mung	48	Sunflower	2	Jowar	76
Nalgonda	Paddy	83	Cotton	106	Mung	94	Castor	40	…	0	Redgram	67
Rangareddy	Paddy	5	Redgram	50	…	0	Maize	20	…	0	Cotton	10
Warangal	Paddy	47	Cotton	45	Cotton	63	Maize	61	Chillies	64	Redgram	61
Proposed for Scenario B												
Adilabad	Cotton	30	Paddy	5	Soyabean	150	…	0	Redgram	300	…	0
Karimnagar	Cotton	30	Paddy	5	Sorghum	168	Maize	102	…	0	Cotton	32
Khammam	Cotton	30	Paddy	20	Maize	70	Maize	30	Mung	166	Cotton	20
Mahbubnagar	Paddy	20	Castor	170	…	0	Maize	63	…	0	Redgram	246
Medak	Paddy	20	Maize	23	Sugarcane	8	Mung	100	Sunflower	2	Jowar	116
Nalgonda	Paddy	33	Cotton	50	Mung	144	Castor	56	…	0	Redgram	107
Rangareddy	Paddy	3	Redgram	70	…	0	Maize	7	…	0	Cotton	5
Warangal	Paddy	15	Cotton	30	Cotton	38	Maize	30	Chillies	74	Redgram	162

Cropping system

Prevailing cropping system in Kharif season

80% of the cultivationarea in almost all the districts is coveredby single predominant crop indicating mono-crop farming system which is highly vulnerable in climatic aberrant conditions. Paddy, cotton and groundnut are major predominant *kharif* crop in the region followed by pulse crops. The district wise predominant rainfed *kharif* crops area are presented in Table 4 and 5.

Unlike rainfed conditions, transplanted paddy is the sole crop that cover 60% of the irrigated area for which groundwater is the major source. This true to the districts of Adilabad, Karimnagar and Khammam. However, irrigated maize and cotton are prevailed in few districts where irrigated area is less than 30%. There are other irrigated crops including pulses, oilseeds and fodder are practiced to substantiate transplanted paddy at limited scale. The district-wise distribution of predominant irrigated *kharif* crop is presented in Table 4.

Prevailing cropping system in rabi season

In *rabi* season,limited area is under cultivation due to inadequate rains. The rainfed crops of *rabi* season include

Table 5: Existing and proposed Cropping Pattern– *Rabi* Season (Area in ,000 ha)

District	Primary crop				Secondary crop				Tertiary crop			
	Rainfed	Area	Irrigated	Area	Rainfed	Area	Irrigated	Area	Rainfed	Area	Irrigated	Area
Adilabad	Jowar	29	Redgram	9	Bengalgram	27	Paddy	8.9	…	0	Wheat	4
Karimnagar	…	0	Paddy	84.2	…	0	Maize	45.6	…	0	Mung	1.6
Khammam	Maize	10	Paddy	32	Greengram	5	Maize	11	Redgram	0.8	…	0
Mahbubnagar	Maize	280	Jowar	20	Groundnut	54	…	0	Paddy	42	…	0
Medak	Paddy	31	Bengalgram	36	Sunflower	14	Jowar	23	Maize	3	Sunflower	8.2
Nalgonda	Paddy	147.7	…	0	Groundnut	16.6	…	0	…	0	…	0
Rangareddy	Paddy	12.1	Chickpea	7.4	…	0	Groundnut	6.8	…	0	Jowar	6.7
Warangal	Bajra	20	Paddy	14	Jowar	7	Chilies	3	Mung	2	…	0
Proposed for Scenario A												
Adilabad	Jowar	29	Redgram	9	Bengalgram	27	Paddy	9	…	0	Wheat	4
Karimnagar	…	0	Paddy	54	…	0	Maize	46	…	0	Mung	32
Khammam	Maize	10	Paddy	17	Greengram	8	Maize	16	Redgram	8	…	0
Mahbubnagar	Maize	170	Jowar	115	Groundnut	104	…	0	Paddy	7	…	0
Medak	Paddy	11	Bengalgram	46	Sunflower	14	Jowar	34	Maize	3	Sunflower	8
Nalgonda	Paddy	88	…	0	Groundnut	77	…	0	…	0	…	0
Rangareddy	Paddy	5	Chickpea	8	…	0	Groundnut	8	…	0	Jowar	12
Warangal	Bajra	20	Paddy	6	Jowar	10	Chilies	7	Mung	3	…	0
Proposed for Scenario B												
Adilabad	Jowar	29	Redgram	9	Bengalgram	27	Paddy	9	…	0	Wheat	4
Karimnagar	…	0	Paddy	34	…	0	Maize	26	…	0	Mung	72
Khammam	Maize	10	Paddy	8	Greengram	15	Maize	6	Redgram	20	…	0
Mahbubnagar	Maize	60	Jowar	267	Groundnut	64	…	0	Paddy	5	…	0
Medak	Paddy	5	Bengalgram	52	Sunflower	14	Jowar	39	Maize	3	Sunflower	3
Nalgonda	Paddy	38	…	0	Groundnut	127	…	0	…	0	…	0
Rangareddy	Paddy	2	Chickpea	5	…	0	Groundnut	3	…	0	Jowar	23
Warangal	Bajra	20	Paddy	6	Jowar	10	Chilies	7	Mung	3	…	0

mostly pulses and fodder. The acreage of primarily dominating crops like Black gram, Bengal Gram and Green Gram are widely spread across the districts of the region.

The region, conventionally witnesses the cultivation of transplanted paddy in *rabi* season which, cover more than 50% of irrigated area. Various pulses and oilseeds are other most preferred crop for irrigated area in *rabi* season. The irrigated area in this season exhibits crop diversification to some extent. However, paddy still preferred but is lesserintensive as compared to other *kharif*. The details of cropping system for *rabi* season is presented in Table 5.

Proposed cropping system for kharif season – Scenario A

The macro-level analysis suggested reducing significant area of paddy and cotton under both rainfed and irrigated condition. This would provide the scope to increase the acreage of maize, redgram and Mung substantially, from 16 to 86, 53 to 165 and 65 to 135thousand ha, respectively. Therefore, significant changes in area under different crops of existing cropping system were suggested in these districts for better water saving and more crop diversity. The change

Table 6: Economic analysis of various scenarios

District	Kharif			RabiIn crore Rs.		
	Cost	Return	B:C Ratio	Cost	Return	B:C Ratio
Adilabad	214.37	338.17	1.58	24.74	71.74	2.90
Karimnagar	142.84	357.6	2.50	49.6	146.84	2.96
Khammam	143.41	311.305	2.17	21.17	57.85	2.73
Mahbubnagar	167.35	417.05	2.49	141.1	251.92	1.79
Medak	100.4	333.5	3.32	37.04	99.02	2.67
Nalgonda	152.675	312.057	2.04	66.85	71.98	1.08
Rangareddy	32.821	95.631	2.91	12.08	28.61	2.37
Warangal	152.49	309.41	2.03	16.39	38.51	2.35
Overall	1098.356	2474.723	2.25	360.64	754.95	2.09
Scenario A						
Adilabad	181.05	337.95	1.87	24.74	71.74	2.90
Karimnagar	128.88	413.86	3.21	43	148.64	3.46
Khammam	129.28	302.15	2.34	19.72	57.74	2.93
Mahbubnagar	160.35	526.05	3.28	135	373.77	2.77
Medak	82.4	311.8	3.78	35.18	116.97	3.32
Nalgonda	139.47	379.37	2.72	69.85	116.38	1.67
Rangareddy	30.7	112.2	3.65	11.28	35.36	3.13
Warangal	133.99	434.71	3.24	15.09	43.48	2.88
Overall	986.12	2818.09	2.86	348.5	952.56	2.73
Scenario B						
Adilabad	156.2	342.2	2.19	24.74	71.74	2.90
Karimnagar	110.48	326.5	2.96	35.4	144.64	4.09
Khammam	98.88	316.36	3.20	17.94	51.72	2.88
Mahbubnagar	160.35	526.05	3.28	135	373.77	2.77
Medak	69.36	303	4.37	35.18	116.97	3.32
Nalgonda	115.43	420.29	3.64	72.35	153.38	2.12
Rangareddy	30.7	112.2	3.65	11.28	35.36	3.13
Warangal	133.58	518.22	3.88	15.09	43.48	2.88
Overall	874.98	2864.82	3.27	341.62	979.54	2.87

includes prominence of other oilseed and pulse crops in existing cropping system. The district-wise allocation of area under different rainfed crop for this scenario is presented in Table4.

Proposed cropping system for rabi season – Scenario A

The existing cropping system in the Adilabad district havingcomposite crop coefficient, K, less than the threshold value of 0.65 and thus no change in the existing cropping system is suggested. The area under rainfedmaize and paddy is suggested to reduce to 183 and 111thousand Ha from 293 and 233thousand Ha, respectively.This provides the scope to substantiallyincreasethe area under rainfed sorghum and groundnut. Substantial area can be put under irrigated sorghum by reducing the acreage of paddy. It is suggested to reduce the area under transplanted paddy by 50% to enhance water productivity and crop diversity. By this preposition 33% additional area can be irrigated from the existing resources. The district-wise allocation of area under different irrigated crop for this scenario is presented in Table5.

Proposed cropping system for kharif season – Scenario B

Scenario B explores the potential to reduce the water requirement by 20 % through change in existing cropping system. Area under rainfed paddy under this scenario may bereduce to111 thousand Ha. The analysis suggested for comprehensive area under pulses such as redgram and *Mung*in 300 and 310 thousand ha, respectively could be realized.This scenario allows more crop diversity as area under other crops including millets and Sorghum, could be increased substantially.In this scenario, additional 233 thousand Ha area could be brought under irrigation from the existing resources. The detailed analysis for this scenario is presented in Table 4.

Proposed cropping system for rabi season – Scenario B

In most of the districts, this scenario is not feasible since the composite crop coefficient is less than the threshold except Karimnagar, Khammam and Nalgonda district. For those districts where this scenario holds good, pulses may be recommended to practices on rainfed area substantially. In this scenario, rainfed Sorghum in 168 thousand ha and *Mung* in 144 thousand ha can be introduced in Karimnagar and Nalgonda district respectively. The proposed area allocation for different crop under this scenario is presented in Table 5.

It is understood that future food production needs of the world would come from rainfed system which spread over several agro-ecological regions and mostly characterized as low productive and non-remunerative. Rainfed agriculture is most prominent in arid, semi-arid and sub-humid regions of Indian subcontinents vis a vis many parts of world including sub-Saharan Africa, Latin America and South Asia. The major ecological and economic factors that make agriculture unsustainable in Indian sub-continent, includes rainfed cultivation, small and fractured land holdings, insufficient crop yield and limited scope to adopt intensive agriculture. However, the water availability and requirement are not the exclusive basis for cultivating these crops. There are many other determinants that defined the traditional farming and those are socio-economic, livelihood, market surplus and employment which also affect the choice of crops during the season. The farming practice also determined by the broader objective of livelihood security and agricultural productivity. Nonetheless agricultural water requirement assumes major importance in agricultural productivity in view of the global challenge of future water scarcity for agriculture.

There is a need to arrive at equilibrium between cropping system (based on prevailing socio-economic and cultural tradition) and its implication on available water resources. In the present study, most of the irrigated paddy area utilizes ground water extensively that exploited the groundwater to the danger zone. But, at the same time other local socio-economic conditions and cultural traditions cannot be ignored completely. Thus,majority of local farmers would be reluctant to adopt comprehensive changes in existing cropping system for sole reason of water productivity. However, more than 20 different crops are cultivated in the region at various extent and magnitude and if changes suggested within the framework of these crops at lower scale, there would be scope for adaptation. Thus, new crop and area were recommended at limited level so that it would easily adapted by the local farmers.

Economic analysis

The various economic parameters were computed for existing and scenario A and B for both the season i.e. *kharif* and *rabi* and is presented in table 6. In case of existing cropping system, the B:C ratio varies from 1.58 (Adilabad district) to 2.91 (Rangareddy District) and 1.08 (Nalgonda district) to 2.96 (Karimnagar district) for *kharif* and *rabi* season respectively. Overall B:C ratio was computed as 2.25 and 2.09 for *kharif* and *rabi* season, respectively. The economics improves significantly in scenario A where it computed as 2.86 and 2.73, respectively. The economical return further improves in the scenario B to 3.27 and 2.87 for *kharif* and *rabi,* respectively.

CONCLUSION

The existing cropping system prevailing in the state of Telangana was evaluated to improve water productivity and crop diversityfor better economical return and livelihood security. The agriculture in major part of the region is found to be dominate by transplanted paddy which leads to mono-cropping and excessive exploitation of ground water which is true for both the season. Considering the large-scale agricultural productivity an issue, re-appropriation was quantified for area under various crops and was based on composite crop coefficient under two scenarios i.e. 10% and 20 % reduction in water requirementcoupled with existing water resources available. The study also envisages the possibility of introduction of new crops such as millet and sorghum at macro level. Most of the analysis indicates the increase in area under pulses and millets in respect to transplanted paddy. The economic analysis suggested that not only the water productivity but also B:C ratio could be enhanced significantly under the envisaged scenarios. The government of Telangana also promoting market led agricultural production system. The present findings based on objectives of water productivity and economical return, would certainly substantiate the initiative of market led agricultural production. Additionally, it is particularly important as these substitutions have the potential to bring nutritional security along with food security in the region. The recommendation thus found could be helpful to the policy makers and implementers who are active in agricultural production and input management at bigger scale.

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