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Estimation of the Water Balance and Length of Growing Period under Gumla District of Jharkhand for Efficient Crop Planning

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ABSTRACT

Present study was conducted for Gumla district of Jharkhand at block level which experiences a humid sub-tropical climate with an average rainfall of 1100 mm annually. In spite of receiving 85% of rainfall during the monsoon season the agricultural production and productivity in the district is quite low due to improper utilization of available moisture during the cropping season. Based on the weekly, annual rainfall and Potential Evapotranspiration (PET) data of 17 years (2000-2016), the length of the growing period (LGP) and water balance was worked out for the district and suitable crop plans were suggested. The length of the growing period was observed to be 21 weeks for most of the blocks of Gumla district under Uplandand an average of 25 weeks under upper medium land situation (Don III). Under lower medium land situation (Don II), length of growing period was of 28-29 weeks for all blocks except Basia, Kamdara and Sisai and low land situation (Don I), possessed 29 weeks of LGP at all blocks whereas it was one week more for Raidih and a week less for Basia and Kamdara.In Basia and Kamdara the water surplus is almost negligible under Upland and Don III land situation and very little water can be harvested from Don II and Don I. Maximum surplus water was observed in Raidih followed by Palkot and can be harvested more water from all land situations. Only short duration varieties of different crop and low water requiring crops like maize and pigeon pea are suitable for Basia as well as Kamdara blocks.

Key words: Crop planning, Gumla, Length of growing period, Water balance.

INTRODUCTION

Availability of water in right quantity and in the right time and its management with suitable agronomic practices are essential for good crop growth and yield. The length of water availability period in a given location varies from year to year and from soil to soil and influences the crop production differently (Ramana Rao *et al.*, 1979a). Rainfed agriculture is besieged by a plethora of risks due to uncertainty of rainfall and recurring drought (Misra, 2005). Thus, crop production under rainfed condition requires intervention of agro-climatic measures to slice down the climatic risks. Hence, precise evaluation of water availability period is an important pre-requisite for crop planning under rainfed condition. The assessment of agroclimatic potential and climatic risk at micro level needs urgent attention for resource allocation and management of rainfed agricultural system more efficiently.

Similar studies were done by Sathyamoorthy *et al.* (2017), to analyze the northwestern zone (NWZ) of Tamil Nadu which aimed to explore the rainfall and its variability over space along with its length of growing period to make crop based decisions.

Water balance parameters like water requirement satisfaction index (WRSI), water deficits etc. are most favorable for yellow sarson in red and lateritic zone and least favorable in coastal saline zone in similar textural classes of soil (Saikia and Saha, 2010).

Fiwaa *et al.* (2014) suggested that the need for designing appropriate agronomic, soil and water management strategies to offset the negative effects of rainfall variability especially for smallholder rainfed agriculture.

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An attempt has been made in this paper to evaluate climatic risks associated with rainfed crop production under water stressed environment and thereby to suggest suitable crops and cropping sequence in Gumla district of Jharkhand at block level for sustainable rainfed crop production based on Index of Moisture Adequacy.

MATERIALS AND METHODS

The study was conducted in 11 blocks of Gumla district of Jharkhand which lies between latitudes 22° 35′ to 23° 33′ N and longitudes 84° 40′ to 85° 1′ E with an elevation of 452-694 meters above mean sea level (MSL), which falls under sub-zone *V* also known as Western Plateau Zone.

The daily weather data such as air temperature (minimum and maximum), relative humidity (morning and evening), rainfall, pan evaporation, wind speed and bright sun shine hours (BSS), from 2000 to 2016 obtained from

various sources such as Department of Agrometeorology and Environmental Science, BAU, Kanke, KVK Gumla, etc. was analysed, processed transformed into Standard Meteorological weekly (SMW) means and totals. Potential evapotranspiration was calculated on weekly and annual basis by using Penman-Monteith (FAO) method. Climatic water balance, based on weekly effective rainfall, of Gumla district were computed by water budgeting approach of Thornthwaite and Mather (1955), taking into account soil storage values for various soil types of the region and using mean weekly potential evaporation value. Topography of Jharkhand is undulating and leading to majorly four types of land situation with different soil texture. Available water holding capacity (AWHC) of different soil types was assumed as 100,150, 200 and 250 mm/m for Tand (Sandy soil), Don III (Sandy loam), Don II (Clay loam) and Don I (Clayey soil) on an average basis, respectively.

For examining the local climate type, the moisture index (Im) is worked out as follows,

$$Im = \frac{\text{Annual water surplus - Annual water deficit}}{\text{Annual potential evapotranspiration}}$$

Moisture index can be computed from the annual water balance parameters such as water surplus (WS), water deficit (WD) and PET.

Aridity Index 'Ia' (%) = 100 * WD/PET
Humidity Index 'Ih' (%) = 100 * WS/PET
Moisture Index 'Im' (%) = Ih - Ia

Climate was categorized on annual basis using moisture index (Im) following Krishnan and Singh (1972).

By using weekly actual evapotranspiration (AET) and weekly potential evapotranspiration (PET), the weekly moisture availability index (MAI) was calculated.

MAI = AET/PET

Where,

For determination of actual Evapotranspiration following two conditions have been considered:

(i) If P>PET,
Then AET=PET

(ii) If P<PET,
Then AET=P+S

Where, P = Precipitation
ΔS = Change in soil moisture

The crop growth period was considered as the period during which the MAI was more than 0.5 at the time of sowing and active vegetative growth period and more than 0.3 at the time of maturity. All periods during active vegetative growth for which MAI was less than 0.5 were considered as stress period. Cessation of rainy season does not mean the end of crop season. Crop can thrive on stored soil moisture and it is therefore, necessary to examine and find out the amount of moisture stored in the soil at the end of the season.

Table 1: Moisture index value and climatic group.

Moisture index value	Climatic group
<-80	Extremely dry
-80 to -60	Semi - dry
-60 to -40	Dry
-40 to -20	Slightly dry
-20 to 0	Slightly moist
0 to 50	Moist
50 to 100	Wet
>100	Extremely wet

RESULTS AND DISCUSSION

Rainfall

The observed average annual rainfall in Gumla district varied from location to location. It was the lowest at Basia (732.1 mm) and the highest at Raidih (1509 mm). The standard deviation and coefficient of variation of annual rainfall over this region varied from 245 to 552 mm and 18 to 37%, respectively. The mean annual rainfall of each of the block under study and their standard deviations with CV% are given in Table 2. The mean and SD's of the rainfall of long period of these blocks fluctuated considerably that is the indication of the annual rainfall variability over Gumla district. Variability was above the threshold value (25%) for Basia, Bishunpur, Dumri, Gumla, Kamdara, Raidih and Sisai blocks indicating unstable or not much dependable rainfall.

Length of growing period

Beginning and end of the rainfed crop growing season were delineated for meteorological weeks at Gumla for all soil conditions from which, the length of the growing period was estimated (Table 3). Results indicated that there is a great variation in the growing period depending on the topographical situations of land. The length of the growing period was observed to be 21 weeks for most of the blocks of Gumla district under upland condition *viz*. Bharno, Bishunpur, Chainpur, Gumla and Palkot. Basia showed shortest growing period of 16 weeks whereas longest growing period of 25 weeks was observed at Raidih. Observed LGP was highest (29 weeks) at Ghaghra, followed by Palkot (28 weeks) and lowest at Basia (22 weeks) under Don III land situation.

Table 2: Average annual rainfall, standard deviation (SD) and coefficient of variation (CV %) of different blocks of Gumla district.

Block	Average Annual Rainfall (mm)	SD	CV%
Basia	732.1	258	35
Bharno	1032.9	266	26
Bishunpur	1040.6	348	33
Chainpur	1074.2	245	23
Dumri	1083.1	298	27
Ghaghra	1205.9	264	22
Gumla	1111.5	332	30
Kamdara	872.3	268	31
Palkot	1225.1	225	18
Raidih	1502.9	552	37
Sisai	1180.7	316	27

Under Don II land situation length of growing period was of 28-29 weeks for all blocks except Basia, Kamdara and Sisai. Basia experienced shortest LGP of 25 weeks while Sisai and Kamdara had LGP of 27 weeks. Low land condition possessed 29 weeks of LGP at all blockswhereas it was one week less for Basia and Kamdara (28 weeks).

Climatic water balance

Results on average weekly water balance were computed following Thornthwaite and Mather (1957) methods for all stations and have been presented in (Table 4 and 5).

Under all locations, due to topographical and soil variations, the effective rainfall varied considerably. It can clearly be seen from Table that the water surplus condition increased within the toposequence (from Upland to Don I) and hence the water deficit decreased.

In Basia and Kamdara with lowest annual rainfall (732.1 and 872.3 mm, respectively, the water surplus is almost negligible under Upland and Don III land situation and very little water can be harvested from Don II and Don I. Maximum surplus water was observed in Raidih followed by Palkot and can be harvested more water from all land situations. At Raidih, which has an annual rainfall of 1502.9 mm, an annual surplus varied from 259 mm to 876 mm for Upland and Don I. Hence, rainwater harvesting during its plenty and its re-use during its scarcity should assume top most priority for ensuring sustainable agriculture in the study areas. Upland areas of Basia and Kamdara, which has fairly low moisture retention capacity, less water requiring tropical crops like pigeon pea and finger millet can be grow successfully.

It can be seen from the Table 6 that most of the blocks come under dry to slightly moist and moist climatic type on the basis of land situation whereas Basia and Kamdara comes under semi dry to slightly dry climatic condition.

Thus the farmer who are having at least two to three types of soil have to plan the crops right from slightly dry type climate to moist type.

In view of the different water related conditions in different land situations, crop diversification would be practicable in uplands as well as in medium lands. Direct seeded rice in upland and direct as well as transplanted rice in medium lands may be replaced, to some extent, with less water requiring crops like maize, oilseeds and pulses. However, in typical lowland (Don I) farmers don't have much option for crop diversification or replacement except to go for transplanted paddy.

Crop planning

Rainfall variability, length of growing period and climatic water balance analyzed under the present study were presented for each block of Gumla district with a view to identify suitable crop plans.

Table 3: Beginning and end of the growing season at different blocks of Gumla district under four land situation.

Blocks	Basia	Bharno	Bishunpur	Chainpur	Dumri	Ghaghra	Gumla	Kamdara	Palkot	Raidih	Sisai
Upland											
LGP	16	21	21	21	20	22	21	19	21	25	22
Beginning- End of Season (SMW)	24-40	24-45	24-45	24-45	24-44	24-46	24-45	25-44	24-45	23-48	24-46
Don III											
LGP	22	26	25	24	25	29	27	22	26	28	26
Beginning- End of Season (SMW)	24-46	24-50	24-49	24-48	23-48	23-52	23-50	24-46	23-49	23-51	24-50
Don II											
LGP	25	28	29	28	28	29	29	27	28	29	27
Beginning- End of Season (SMW)	24-49	23-51	23-52	23-51	23-51	23-52	23-52	24-51	23-51	23-52	24-51
Don I											
LGP	28	29	30	29	29	29	29	28	29	29	29
Beginning- End of Season (SMW)	23-51	23-52	22-52	23-52	23-52	23-52	23-52	24-52	23-52	23-52	23-52

Table 4: Water surplus under different land situation at blocks of Gumla district.

Blocks/Land type	Basia	Bharno	Bishunpur	Chainpur	Dumri	Ghaghra	Gumla	Kamdara	Palkot	Raidih	Sisai
Upland	Nil	55	50	80	80	101	70	Nil	138	259	124
Don III	Nil	160	163	208	203	234	185	77	284	455	263
Don II	44	279	290	344	336	376	316	170	436	518	413
Don I	115	406	417	462	471	533	453	270	596	876	570

Table 5: Water deficit under different land situation at blocks of Gumla district.

Blocks/Land type	Basia	Bharno	Bishunpur	Chainpur	Dumri	Ghaghra	Gumla	Kamdara	Palkot	Raidih	Sisai
Upland	807	686	673	693	686	631	652	792	658	622	670
Don III	692	620	612	638	623	563	586	659	592	561	606
Don II	633	575	571	597	583	512	538	624	544	633	564
Don I	603	549	535	560	548	478	502	593	504	485	531

Table 6: Moisture Index (Im) and climatic type of different land situation of Gumla district.

Block/Land type	Basia	Bharno	Bishun-pur	Chainpur	Dumri	Ghaghra	Gumla	Kamdara	Palkot	Raidih	Sisai
Upland	-64.4	-50.6	-50	-49	-48.4	-42.5	-46.6	-58.3	-41.5	-29	-43.8
	(Semi-dry)	(Dry)	(Dry)	(Dry)	(Dry)	(Dry)	(Dry)	(Dry)	(Dry)	(Slightly dry)	(Dry)
Don III	-55.2	-36.9	-36.1	-34.4	16.2	-26.4	-32.1	-46.6	-24.6	-8.5	-27.5
	(Dry)	(Slightly dry)	(Slightly dry)	(Slightly dry)	(Slightly dry)	(Slightly dry)	(Slightly dry)	(Dry)	(Slightly dry)	(Slightly moist)	(Slightly dry)
Don II	-47	-23.7	-22.6	-21	-19.7	-10.9	-17.8	-36.3	-8.6	11.6	-12.1
	(Dry)	(Slightly dry)	(Slightly dry)	(Slightly dry)	(Slightly moist)	(Slightly moist)	(Slightly moist)	(Slightly dry)	(Slightly moist)	(Moist)	(Slightly moist)
Don I	-38.9	-11.5	-9.5	-7.8	-6.2	4.4	-3.9	-25.8	7.3	31.2	3.1
	(Slightly dry)	(Slightly moist)	(Slightly moist)	(Slightly moist)	(Slightly moist)	(Moist)	(Slightly moist)	(Slightly dry)	(Moist)	(Moist)	(Moist)

The crop plans were prepared for prevailing three land situations- upland, medium land and lowlands on which cropping is entirely different. Three identified weather conditions were also considered i.e. Normal, Early drought (upto 15th July) and Late drought (upto 15th August) condition as detailed below:

1. Normal: The crop seasons (*kharif*) availing normal weather condition throughout the season and not faced any dry spell (>2 weeks)/drought.

2. Early season drought: The crop season (*kharif*) faced mild/moderate drought/2-3 week dry spell upto 15th July.

3. Late season drought: The crop season (*kharif*) faced mild/moderate drought or/ 2-3 weeks dry spell from 3rd week of July to 15th August.

On the basis of rainfall characterization blocks of Gumla district can be divided into three homogenous groups for proper crop planning.

The planning of these blocks was done taking into the consideration of agroclimatic characteristics like water balance and length of growing period, which has been already explained, are tabulated below:

Table 7: Grouping of blocks of Gumla district.

Groups	Average Annual Rainfall	Blocks
Group A	< 1000 mm.	Basia and Kamdara
Group B	1000 – 1200 mm	Bharno, Bishunpur, Chainpur, Dumri, Gumla and Sisai
Group C	>1200 mm	Ghaghara, Palkot and Raidih

Group A (Basia and Kamdara Block)

These two blocks received average annual rainfall of less than 1000 mm. Water surplus under upland and Don III land situation was also nil with shorter length of growing period. Change in existing cropping pattern is required for this group. Rice cultivation in upland and Don II can be replaced by Ragi and Early potato. Under late drought condition Buck wheat can be recommended in place of niger as more profitable and nutritious crop. Main crops recommended for uplands are maize, pigeonpea, urd bean, mung and ground nut either as sole crops or intercrops in different combinations. As intercropping is more beneficial, following established intercropping combinations were recommended with an advice to complete sowing of crops on uplands by the end of June. Recommended intercropping for normal weather conditions are Pigeon pea + Maize, Maize+ Okra, Maize + Mung, Pigeon pea + Groundnut, Gram + Turmeric/ Ginger (Table 8).

Lac is a natural heritage of Jharkhand and it is associated with tribal and poor people providing regular income in absence of other cash crops. Basia and Kamdara can be a potential area for lac cultivation. Promotion of scientific lac cultivation by growinglac host trees i.e. kusum, palash, ber etc. is an assured ecological approach for

Table 8: Crop planning for Basia and Kamdara blocks.

Land situation	Normal (2nd Fortnight of June)	Early drought (upto-15th July)	Late drought (upto-15th August)
Upland **Don III** **+** **Don II** **(Medium Land)**	**Sole crop:** Pigeon pea, Black gram, Maize, Ragi. **Intercrop:** Pigeon pea + Maize, Maize + Okra, Maize + Mung, Pigeon pea + G/nut, Gram + Turmeric/ Ginger. ***Varieties:*** Maize- Swan composite, Birsamakka 1 Black gram: Indira urd pratham, WBU-109, UH-1 Pigeon pea: PP9-22, Bahar, Birsa arhar-1 Okra: Prabhani kranti, Arka anamika, A-4 G/nut: Birsa groundnut 4, Birsa bold, AK-12, 14 Ginger: Vardhaman, Suruchi, Suprabha, Nadia Turmeric: Rajendra Cowpea: UPC 625, UPC 622, Bundellobia 2 **Sole crop:** Rice ***Varieties:*** Rice - IR-64 Drt-1, Birsadhan 201, Lalat Soybean: RAUS 5, MAUS 71 Brinjal: Pusa purple long, Vijay, Muktakeshi Amaranthus: Co-2, VL Chua-44, Arka arunima Berseem: Bardaan Sorghum: CSV 20, CSV 17 Coriander: Rajendra swati, Pant HKS, Gujarat dhania 1	*Discard Rice **Sole crop:** Pigeon pea, Rainy potato, Finger millet, Maize, Black gram, Sorghum, Cucurbits, Tomato, Sweet potato. **Intercrop:** Pigeon pea + Lady's finger (1:2), Maize + Cowpea (1:2), Pigeon pea + Groundnut (1:2), Pigeon pea + Sorghum (1:1). ***Varieties:*** Rainy potato: Kufri himalini, Kufri surya, Kufri pushkar Finger millet: Birsa marua-2, A- 404 Sorghum: CSV 20, CSV 17 Tomato: Swarna lalima, Arka abha, BT 12 Sweet potato: Shribhrada, Kalinga, Gauri Lady's finger: Prabhani kranti, Phule kirti ❖ Replace rice with pulses, vegetable, fodder crop, Pigeon pea/Sorghum. **Pulses:** Black gram, Soybean, Cowpea, Pigeon pea. **Vegetables:** Lady's Finger, Amaranthus leaf, Coriander leaf, Tomato, Brinjal, French bean, Sweet potato **Intercrop:** Pigeon pea+ Fodder (2:1), Pigeon pea + Black gram, Maize, Lady's Finger, Finger Millet **Fodder Crop:** Sorghum, Brachiaria grass, Ginuea grass, Rice bean (Moth bean), Maize, Cowpea, Berseem	**Sole crop:** Kulthi, Niger, Buck wheat, Potato. Intercrops: Pigeon pea + maize (fodder), Maize (fodder) + cowpea (fodder), Lady's finger + Maize (fodder) ***Varieties:*** Maize (fodder): African tall Niger: Birsa niger 1-2, BNS 10 Rice bean (Moth bean): IPR 96-4, Gujarat Dantiwada Horsegram1 (GHG-5 Potato: Kufri jyoti, Kufri jawahar ❖ **DSR** (Improved rice varieties): IR- 64, Drt 1, Shabhagi dhan, Abhishek, Hazari dhan ❖ **Transplanting:** Hybrid rice varieties) Var. :Arize Tej (Gold), PAC 801, 807
Don I **(Lowland)**	**Sole crop:Rice** ***Varieties:*** Rice -MTU-7029, MTU-1010, Tulsimanjri, Karaihani	❖ Change in crop and cropping system. ❖ Discard Long duration variety (eg.: Swarna, BPT 5204 and Rajshree) ❖ Replace Late duration with Medium duration rice variety of Don II in Don I ❖ DSR ❖ Transplanting (Hybrid rice varieties)	❖ If possible, go for staggered nursery raising in rice crop. ❖ If possible, raise community nursery of rice at a reliable water source to save time for further delay. ❖ In case, if rice population is less than 40-50 percent, gap filled by re-transplanting the rice crop.

Table 9: Crop planning for Bharno, Bishunpur, Chainpur, Dumri, Gumla and Sisai blocks.

Land situation	Normal (2nd Fortnight of June)	Early drought (upto-15th July)	Late drought (upto-15th August)
Upland	**Sole crop:** Rice, Pigeon pea, Black gram, Maize **Intercrop:** Pigeon pea + Maize, Maize + Okra, Maize + Mung, Pigeon pea + G/nut, Red gram + Turmeric/Ginger. ***Varieties:*** Rice: Vandana, Birsa 108, Birsa vikasdhan 109, 110 Maize: Swan composite, Birsa makka 1, HQPM-1 Pigeon pea: PP9-22, Birsa arhar-1, Bahar Blackgram: Indira urd pratham, WBU-109, UH-1 Finger millet: Birsa marua-2, A- 404	***Discard Rice.** **Sole crop:** Pigeon pea, Rainy potato, Finger millet, Maize, Black gram, Sorghum, Tomato, Sweet potato, Cucurbits. **Intercrop:** Pigeon pea + Okra (1:2), Maize + Cowpea (1:2), Pigeon pea + Groundnut (1:2), Pigeon pea + Sorghum (1:1). ***Varieties:*** Okra: Prabhani kranti, Arka anamika,A-4 G/nut: Birsa groundnut4, Birsa bold, AK-12 - 14	**Sole crop:** Horse gram, Niger, Buck wheat, Potato. **Intercrops:** Pigeon pea + maize (fodder), Maize (fodder) + cowpea (fodder), Okra + Maize (fodder). ***Varieties:*** Mung: Pusa vishal, SML-688 Lady's finger: Prabhani kranti, Phulekirti Ginger: Vardhaman, Suruchi, Suprabha, Nadia Turmeric: Rajendra
Don III + Don II (Medium Land)	**Sole crop:** Rice ***Varieties:*** Rice:, IR-64 Drt-1, Birsadhan 201, Lalat, Sahabhagi, Naveen Sorghum: CSV 20, CSV 17 Maize (fodder): African tall Berseem: Bardaan Cowpea:UPC 625, UPC 622, Bundellobia2 French bean: Pant anupama, Birsa priya Sweet potato: Shribhrada, Kalinga, Gauri Rice bean (Moth bean):Gujarat Dantiwada Horsegram1 (GHG-5), IPR 96-4	❖ Replace rice with Pulses, vegetable, fodder crop, Pigeon pea, Sorghum etc. **Pulses:** Black gram, Soybean, Cowpea, Maize, Lady's finger, Finger millet. **Vegetables:** Lady's finger, Amaranthus leaf, Coriander leaf, Tomato, Brinjal, French bean, Sweet potato. **Fodder Crop:** Sorghum, Brachiaria grass, Rice bean (Moth bean), Maize, Cowpea, Berseem. **Intercrop:** Pigeon pea+ Fodder (2:1), Pigeon pea + Black gram.	❖ DSR (Improved rice varieties) *Var:* IR-64 Drt 1, Shabhagi dhan, Abhishek, Hazari dhan. ❖ Transplanting: Hybrid rice varieties: Arize Tej (Gold), PAC 801, 807. ***Varieties:*** Amaranthus: Co-2, VL Chua-44, Arka arunima Coriander: Rajendra swati, Pant HKS, Gujaratdhania 1 Tomato: Swarna lalima, Arka abha, BT 12 Brinjal: Pusa purple long, Vijay, Muktakeshi
Don I (Lowl and)	**Sole crop**: Rice ***Varieties:*** Rice: MTU-7029, MTU-1010, Tulsimanjri, Karaihani	❖ Discard Long duration variety (Swarna, BPT 5204 and Rajshree). ❖ Replace Late duration with Medium duration rice variety of Don II in Don I. ❖ DSR (Improved rice). ❖ Transplanting hybrid rice varieties.	❖ If possible, go for staggered nursery raising in rice crop. ❖ If possible, raise community nursery of rice at a reliable water source to save time for further delay. ❖ In case, if rice population is less than 40-50 percent, gap filled by re-transplanting the rice crop.

Table 10: Crop planning for Ghaghra, Palkot and Raidih blocks.

Land situation	Normal (2nd Fortnight of June)	Early drought (upto-15th July)	Late drought (upto-15th August)
Upland	**Sole crop:** Rice, Pigeon pea, Black gram, Maize. **Intercrop:** Pigeon pea + Maize, Maize+ Okra, Maize + Mung, Pigeon pea + G/nut, Red gram + Turmeric/Ginger. Rice: Vandana, Birsa 108, Birsa vikas dhan 109, 110 ***Varieties:*** Maize: Swan composite, Birsa makka 1 Black gram: Indira urd pratham, WBU-109, UH-1 Pigeon pea: PP9-22, Birsa arhar-1, Bahar Okra: Prabhanikranti, Arka anamika, A-4 G/nut: Birsa groundnut 4, Birsa bold, AK-12-14	**Sole crop:** Pigeon pea, Rainy potato, Finger millet, Maize, Black gram, Sorghum, Cucurbits, Tomato, Sweet potato **Intercrop:** Pigeon pea + Lady's finger (1:2), Maize + Cowpea (1:2), Pigeon pea + Groundnut (1:2), Pigeon pea + Sorghum (1:1) ***Varieties:*** Rainy potato: Kufri surya, Kufri pushkar, Kufri himalini Finger millet: Birsa marua-2, A- 404 Mung: IPM 2-3, Pant mung 2-4, Narendra mung 1 Cowpea: UPC 625, UPC 622, Bundellobia2 Ginger: Vardhaman, Suruchi, Suprabha, Nadia	**Sole crop:** Kulthi, Niger, Buck wheat, Potato. **Intercrops:** Pigeon pea + maize (fodder), Maize (fodder) + cowpea (fodder), Lady's finger + Maize (fodder). ***Varieties:*** Maize (fodder): African tall Niger: Birsa niger 1, 2, BNS 10 Rice bean (Moth bean): IPR 96-4, Gujarat Dantiwada Horsegram1 (GHG-5 Potato: Kufri jyoti, Kufri jawahar Turmeric: Rajendra
Don III + Don II (Medium Land)	❖ **Sole crop:** Rice, Sugarcane ***Varieties:*** Rice - IR-64 Drt-1, Birsadhan 201, Lalat Sweet potato: Shribhrada, Kalinga, Gauri Lady's finger: Prabhanikranti, Phulekirti Sorghum: CSV 20, CSV 17 Tomato: Swarna lalima, Arka abha, BT 12 Sugarcane: Karan 12, CoP 2061, Imarti	❖ **Pulses:** Black gram, Soybean, Cowpea. ❖ **Vegetables:** Lady's Finger, Amaranthus leaf, Tomato, Coriander leaf, Brinjal, French bean, Sweet potato. ❖ **Intercrop:** Pigeon pea + Fodder (2:1), Pigeon pea + Black gram, Maize, Lady's Finger, Finger Millet ❖ **Fodder Crop:** Sorghum, Brachiaria grass, Ginuea grass, Rice bean (Moth bean), Maize, Cowpea, Berseem	❖ **DSR** (Improved rice varieties): IR- 64, Drt 1, Shabhagi dhan, Abhishek, Hazaridhan ❖ **Transplanting:** Hybrid rice varieties) Var.- Arize Tej (Gold), PAC 801, 807
Don I (Lowland)	v **Sole crop:** Rice ***Varieties:*** Rice -MTU-7029, MTU-1010, Tulsimanjri, Karaihani	❖ Medium duration rice varieties of Don II can be replaced with Late duration rice varieties in Don I. ❖ Long duration varieties such as Swarna, BPT 5204 and Rajshree can be taken. ❖ DSR (Improved rice). ❖ Transplanting (Hybrid rice varieties).	❖ If possible, go for staggered nursery raising in rice crop. ❖ If possible, raise community nursery of rice at a reliable water source to save time for further delay ❖ In case, if rice population is less than 40-50 percent, gap filled by re-transplanting the rice crop. ❖ Residual moisture can be used for the succeeding *Rabi* crops.

developing lac based diversified farming system for increased productivity and profitability.

Group B (Bharno, Bishunpur, Chainpur Dumri, Gumla and Sisai)

Rainfall characteristics, length of growing period and climatic water balanceshowed that these blocks are suitable for wide range of crops. Uplands are suitable for direct seeded short duration (90-90 days) riceas well as Pigeon pea, Black gram and maize crops. Details of crops with their varieties under different situations are presented in Table 9.

Group C (Ghaghara, Palkot and Raidih)

These blocks are the highest rainfall recipient region of Gumla district with longest length of growing period and considerable surplus water. Area is suitable for the crops recommended in Table 10 under different land and weather conditions. High water requiring crop like sugarcane can be a potential crop for these blocks. Plenty of water can be harvested in monsoon season and reuse for irrigation in *rabi* season to increase the cropping intensity.

CONCLUSION

Basia and Kamdarablocks receiving low seasonal rainfall with high inter annual variability and presence of some mountains (i.e., Gherapahar) leads to formation of a rain shadow area and crops like rice are at high risk due to crop failure. Ragi, pigeon pea, maize should be promoted as a *kharif* crops which require less water. Change in the existing cropping pattern with an introduction of maize-potato. During late drought condition Niger should be replaced by buck wheat which seems to be a more profitable and nutritious crop. In midland condition, medium duration rice varieties such as IR-36, IR-64, Birsa dhan 201, Lalat, Naveen, Sahabhagi, MTU-1010 *etc*. are recommended and in lowland areas rice varieties such as MTU-7029, Tulsimanjri, Karaihani Rajshree *etc*. give higher yield.

Raidih and Palkot blocks are the potential areas for rice cultivation and this potential needs to be exploited. Medium to long duration varieties *viz*. Sahbhagi, Naveen, Lalat, Swarna, BPT 5204, Rajshree etc. are recommended. Most of the blocks of Gumla district have greater chance for water surplus during their rainy season thus offer opportunity for water harvesting and supplemented irrigation to mitigate drought. It can prove beneficial for successive *rabi* crops also.

During *rabi* season, large area in the district is under fallow after *kharif* rice cultivation and has potential to grow low water requiring crops like pulses and oilseeds with excess rain water harvested in ponds and reservoirs in most of the blocks.Crop diversification would be practicable in uplands as well as in medium lands.Direct seeded rice in upland and direct as well as transplanted rice in medium lands may be replaced, to some extent, with less water requiring crops like maize, oilseeds and pulses. However, in typical lowland (Don I) farmers don't have much option for crop diversification or replacement except to go for transplanted paddy.

Water balance and length of growing period which are important parameter for agroclimatic characterization witnessed the large climate variability in Gumla district hence, it can be recommended to promote allied activities like Lac production and Bee keeping in context to climate resilient agriculture.

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