Crop production under spate irrigation in coastal areas of PDRY

Ab.S. Mu'Allem
El-Kod Agricultural Research Centre

1. Introduction

The need for irrigation in the coastal regions, either from floods or from pumped groundwater from the aquifer, is evident. The weather is hot and dry, with maximum and minimum temperatures of 36 and 27 C in the summer, and 28 and 23 C in the winter, as can be seen in Table 1. The relative humidity is high throughout the year, averaging 81 percent. Rainfall is low and erratic and seldom exceeds 60 mm per annum.

Spate irrigation is believed to be of good quality, with lower running and initial investment costs than underground water irrigation. However, there are some technical and administrative problems with this system of irrigation. For example, traditionally, water was diverted by large earth dams (ogmas) built across the Wadis. Once an ogma was breached, there was usually no opportunity to rebuild it until the end of the flood season. A heavy flood, early in the season could prove disastrous by sweeping through to the sea (Anthony, 1971). Priority was therefore given, after independence, to the replacement of ogmas by permanent structures, as and when funds were available. Water is now diverted to fields by a system of headworks, weirs, off-takes, regulators and canals. Single fields are surrounded by earth banks to impound water and are usually disc ploughed at the end of each season in preparation of the following crop.

2. Cropping pattern under spate irrigation

Variations in water supply affect the annual cropped area, and hence crop production. Table 2 indicates that there are two distinct flood periods of Seif (April and May) and Kharif (July-September). These produce over 83 percent of the average flows and (during Kharif) the lowest coefficients of variation (C.V.). The data indicate that spate irrigation restricts all agricultural activities to these two definite periods, thus creating peak labour requirement periods for most of the production facilities.

Table 3 gives the mean and median values of water flow for each of the 13 weeks between 1st July and 30th September inclusive, for the years 1951-59. Except for week 12, the mean weekly values increase and decrease within a peak during weeks 7, 8, 9; 13th August to 2nd

Table 1. Summary of El-Kod meteorological data, representing coastal area region, cropping season 1982-83 Lat 13 05' N, Long. 45 20' E, altitude 5 mabove sea level

	Temperature °C Max	Temperature °C Min	Relative Humidity %	Sunshine Daily Mean h	Wind ht 2m km/h	Rain mm	Daily total* radiation cal/cm² (1)	Daily total* radiation cal/cm² (2)	Computed Evaporation mm
January	27.8	22.8	81.5	8.2	7.0	10.0	450	504	9.1
February	29.1	23.3	82.2	8.3	6.4	-	510	554	9.7
March	30.5	23.0	83.0	8.1	6.6	35.1	555	555	10.9
April	32.0	24.7	81.0	7.2	6.0	-	604	606	9.7
May	33.6	25.6	78.3	10.2	5.2	-	590	589	9.1
June	36.0	27.3	78.7	8.8	5.0	-	533	527	11.3
July	35.8	28.2	75.0	7.0	6.2	0.5	468	456	10.1
August	34.6	27.8	80.2	6.8	6.7	0.3	533	525	10.0
September	34.9	27.3	83.4	7.2	5.5	1.0	546	562	7.5
October	31.9	23.4	82.5	9.6	6.0	1.7	521	542	6.6
November	30.3	22.9	81.3	9.2	5.4	0.2	449	478	8.0
December	28.9	22.3	81.3	7.3	6.0	8.5	408	468	8.2

* Cropping season 1961-62
(1) Kipp Solarimeter
(2) Gunn-Bellani radiation integrator calibrated from Kipp Solarimeter

Table 2. Monthly floods flow of the Wadi Bana, Abyan Delta, coastal area region (million m³)

	number of years	average flow	median flow	C.V. %
April	12	16.0	11.6	93
May	13	15.3	8.3	154
June	13	5.7	3.4	93
July	13	25.5	17.9	70
August	12	57.2	52.2	56
September	12	25.6	22.4	62
October	12	5.5	4.0	115
November	12	2.8	2.3	83
December	12	3.5	2.3	86
January	12	2.6	1.4	160
February	12	1.5	1.5	88
March	12	6.4	4.5	98

September. The high value for week 12 is due to an anomalous single large flood received in 1955. The values for each nine-week period are shown in Table 4 and there is little to choose between the means of the periods and their measured variation over a period of nine years.

The long term mean of period (4-12) is almost certainly the same as, or smaller, than that of period (3-11) owing to the anomalous value for week 12. The data indicate that the period (3-11), i.e. July 15 to September 16, is best to irrigate and sow the main cash crop (extra long and medium-staple cottons). Also, the volume of water received outside the maximum allowable cotton irrigation period is almost half the total. Used efficiently, this could produce an average acreage of other crops nearly equal to the maximum possible acreage of cotton. Ogborn[9] reported that restriction of the cotton irrigation to nine weeks might reduce the potential acreage by 18 percent. However, this loss of acreage must be balanced against the increased

Table 3. Weekly flood flow, July 1 - September 30 (1951-59) of the Wadi Bana, Abyan Delta, coastal area region (million m³)

Week	Mean Value	Median Value
1	2.8	1.3
2	3.4	2.2
3	6.4	5.5
4	7.9	5.2
5	15.2	13.6
6	12.3	12.3
7	14.2	10.1
8	14.3	11.6
9	14.0	10.7
10	8.7	7.8
11	6.4	7.9
12	8.7	3.0
13	2.9	1.5

Source: Ogborn, J.E.A.(9) (1961), Prog. Rep. Exp. Stas. Emp. Cott. Gr. Corp. 1959-60. Aden Protectorate, P.14

yields and improved cotton grades which may be expected in a crop free from bollworm damage.

Proctor[11] showed that, after the cultivation of cotton, spate land should be watered the next year, during the period April to September, if possible. Table 5 shows the extent to which this is possible. It will be noted that in eight of eleven years, the April to September supply exceeded the previous season's cotton supply. If all water supplies had been used with equal efficiency, as suggested by Proctor[11] a high degree of entomological control, specifically against Sudan bollworm (*Diparopsis watersi (Roths)*) could have been achieved.

However, for a number of reasons, both administrative and technical, the smaller flows of the Seif flood are, at present, used much less efficiently than those of the Kharif flood.

Practical schemes for progressive watering and cropping are possible, despite the marked seasonal variations in supply. Effective irrigation control and distribution become possible with the completion of major irrigation works, and the lining of canals. Spate irrigation, by itself, however, limits the range of crops under cultivation to those that can grow after a single preplanting flooding.

Table 4. Mean flood flow for possible cotton sowing period (million m³)

Week	Mean	C.V. %
(1-9)	90.5	42
(2-10)	96.4	40
(3-11)	99.4	41
(4-12)	101.8	38
(5-13)	96.8	38

Source: Ogborn, J.E.A.(9) (1961). Prog. Rep. Exp. Stas. Emp. Cott. Gr. Corp. 1959-60. Aden Protectorate. P.15

3. Spate irrigation applications

The traditional practice is a single preplanting irrigation of 60-100 cm of water, depending on basin embankment height and field level. This is sufficient (Table 6) to cover water requirements for all spate irrigated field crops, provided that the moisture holding capacity of the soil is satisfactory. Podchivalov[10] and Rijks[12] calculated the available water of soils with different textural groups (Table 7), and related that to cotton yields (Table 8). Table 7 shows that loamy sands have a very low available water per 100 cm of soil depth; one water application a year to a soil of this textural class is wasteful, since most of water applied percolates to a greater depth.

Table 8 indicates that available water in the active root zone is associated with cotton yield response. The result is consistent with the findings of Podchivalov[10] who found that in light soils with low moisture holding capacity, application of higher amounts of flood water resulted in poor yields. He assumed that if extra long-staple cotton, which requires 71.5 to 78.5 cm of water, was grown in a clay loam soil with an available water of 50.0 cm at the 3 m depth, the deficit will be 21.5 to 28.5 cm, equivalent to 30 percent of the crop water requirement. With this water deficit, cotton yield did not exceed 400 kg/acre. Therefore, where a single pre-planting irrigation is the main practice, the moisture holding capacity of the soil, and its available water content, should be the main criterion for classifying soils for the cultivation of different spate irrigated crops. Similar results have been reported by ITAL-Consult (1973), El Kod Research Station and the Soviet-Yemeni projects for Abyan Delta and Wadi Tuban.

Traditionally, the quantity of water supplied to fields depended on the whim of individual farmers. They often assumed that it was advantageous to apply a large amount. The unevenness of fields also contributed to over-watering, as farmers attempted to raise water to levels at which they could water the highest places (Anthony, 1971).

4. Water quality and salinity

Ogborn[9] reported that irrigation water from the wadis in the Abyan Delta has a salt content of 6-10 meq/l. The principle cations are sodium (50 percent), calcium and magnesium, while the principle anion, bicarbonate, invariably exceeds the total of the calcium and magnesium ions. He has shown that this irrigation water leads to saline and alkaline deterioration of soil wherever the water table rises high enough to keep the surface soil wet and exposed to evaporation for a long period. He estimated that 7 000 acres were affected by this saline-alkaline deterioration in 1955.

Another hydrological survey in the mid-1960s showed that about 4 500 acres of Abyan Delta had a water table of less than 2 m deep (*i.e.*, with salinity hazards) and about a further 5 500 acres had a water table 2-3 m deep. However, the low clay content of the silty-clay loams and silt loams enables comparatively rapid reversion to a non saline-alkaline state wherever the water table is lowered sufficiently to allow effective leaching. Recently, the water table appears to have dropped and there has been no visible extension of saline areas. This was due to the better water control after independence.

Table 5. Relationship between April-September supply and previous year's cotton supply

Season	Previous cotton supply (million m³)	April-September supply (million m³)
1949-50	57.2	79.4
1950-51	55.2	148.6
1951-52	56.4	181.7
1952-53	147.7	96.9
1953-54	86.9	156.9
1954-55	65.9	208.3
1955-56	145.4	97.8
1956-57	64.1	100.5
1957-58	67.0	157.3
1958-59	81.2	61.1
1959-60	48.0	121.3

Source: Ogborn, J.E.A.(9) (1961). Prog. Rep. Exp. Stas. Emp. Cott. Gr. Corp. 1959-60. Aden Protectorate. p.16.

5. Frequency of irrigation

Podchivalov[10] suggested that the water requirement for any crop is determined not only by the climatic conditions of the area but by the length of the inter irrigation period as well. He further stated that with a single preplanting irrigation, this period is determined by the intensity of the irrigated area utilization during a year, and cropping sequence. It can vary from 3 to 18 months as follows:

- when sorghum and melons have been planted as a result of Seif flood flow during March to May. If flooding is carried out on the same land during July to mid-September of the same year after harvesting

Table 6. Calculated net water requirements for spate irrigated crops in Al-Arais State Farm, Wadi Tuban Delta, coastal region

Crop	Planting date	Harvest date	Days to harvest	Water requirement (m³/acre)
Sorghum (Grain)	August	October	90	4350
	September	November	90	4200
Sorghum (Forage)	April	May	50-60	1350-1820
Cotton (Long-Staple)	August	Jan-March	240	7850
	Sept 15	Jan-April	225	7150
Cotton (Med Staple)	August	Dec-Feb	212	5780
	Sept 15	Dec-Feb	195	5360
Melons	August	October	90	3550
	November	January	90	3450
Sesame	August	October	90	4200
	October	December	90	4100

Source: Podchivalov, V.(10) (1983). "Problems affecting growth of various crops under spate irrigation in PDR Yemen and recommendations for solutions".
A Technical Report, Development of Improved Farming Systems and Extension, PDY/81/001

Table 7. Available water in soils in different textural classes in the Abyan Delta, Coastal Region, 1965

Textural class	Available water in 1 m of soil (cm)
Loamy sand	3.9
Sandy loam	8.3
Loam	13.8
Silt loam	16.3
Clay loam	17.0
Silty Clay Loam	20.2

Source: Rijks, D.A.(12) (1965) "The Use of Water by Cotton Crops in Abyan, South Arabia". *J.App. Ecol*. 2:317-43.

these two crops, and cotton or any other crop, is planted after this flooding, then the frequency of irrigation makes about 5 months;

- when cotton is planted in an area previously planted with cotton, frequency of irrigation is 12 months; and
- when cotton is planted in an area previously planted during the Seif period of the preceding year with grain sorghum. In this case, the frequency of irrigation will make 15-18 months.

Based on these facts, Podchivalov[10] suggested that when the depth of soil layer is more than 3 m and frequency of irrigation is equal to 12 or more months, net irrigation rate might be accepted as equal to 60 cm. However, when the frequency of irrigation is 5 months, the net irrigation rate makes up 35-40 cm. He concluded that for more efficient use of irrigation water, it is necessary to increase the irrigation intensity (or decrease the frequency of irrigation). Irrigation water should be concentrated on areas which were already planted with crops and irrigated twice a year.

The interval between flooding the land and the planting of any crop is also important in determining the availability of water to crop plants. With a long interval, water is lost by evaporation from the soil surface, and by deep percolation. Podchivalov[10] reported that for a depth of 2 m, the loss will be 9.01 cm, 30 and 24 percent of water of soils with holding capacities of 30.2 cm and 37.85 cm, respectively. For example, in soil with a water holding capacity of 30.2 cm, the loss of 9.01 cm will leave 21.2 cm of available water. This is only capable of supporting a sorghum crop which has a water requirement of 13.5 cm. If the water holding capacity of the soil is 37.85 cm, then the loss of 9.01 cm will leave 28.8 cm, resulting in a serious reduction of cotton yield which has a water requirement of 71.5-78.5 cm. It is important, therefore, to start tillage operations and sow crops as quickly as possible after flooding.

Table 8. Expected yield of cotton lint, Abyan Delta, Copt Coastal Region, 1965

Available water (cm)	Expected yield (kg/acre)
26 -50	200-400
12.5-25	120-200
Less than 12.5	less than 120

Source: Rijks, D.A.(12) (1965) "The Use of Water by Cotton Crop in Abyan, South Arabia". *J.App. Ecol*. 2:317-43.

6. Spate soils

Spate irrigation has been practised for centuries in the coastal region deltas. Annual sedimentation has slowly raised the original soil level by 8-10 m, resulting in deep soils. However, in some areas, the sedimentation has only raised the level of the soil a few centimetres, resulting in shallow soils. Some deep soils may restrict root growth because of stratification caused by frequent textural changes in the soil profile. The root system of crops with tap roots diminish more rapidly in such soils than in soils with uniform profiles. Strong stratification is likely, therefore, to limit the effective rooting zone. From this, Podchivalov[10] suggested that the effective rooting zone of most field crops is about 3 m deep.

Continuous flood irrigation may also result in the formation of a hard compact layer at different depths. According to Podchivalov[10], this compact layer was caused by the dispersion of clay particles carried in the flood water which are then washed down the profile. The formation of such a layer restricts the soil volume from which the root system absorbs water resulting in reduced productivity. Every 2-3 years, the hard pan should be broken up by chiselling using a heavy power unit. The depth of chiselling should be 40-45 cm to destroy the compact layer, usually found at a depth of 30-40 cm.

7. Fertilizer use

Fertilizers were not used commercially in spate irrigated areas. In the past, many farmers believed that the nutrient requirements of their crops were met by silt deposits following flooding. Early studies have indicated that the silt content of flood water in the Wadis Bana and Hassan of Abyan Delta exceeds 1 percent by weight depositing, on average, 1.5 cm of silt in a heavily watered field. Anthony[2] reported that 1 m depth of silt-laden water per acre contains about 2.27 kg nitrogen, 0.027 kg phosphate and 27.22 kg potash. However, short-term benefit has been detected from silt in field experiments; older areas benefited from nitrogen fertilizer, but showed no response to phosphate or potash.

Applying nitrogen fertilizer after or during flood irrigation gave anomalous results. The responses to nitrogen were usually moderate to good when the cotton or other crops had received a moderate watering, but negligible where watering was light or heavy. The poor response obtained on heavily watered soil was thought to be caused by a higher rate of evaporation from the soil surface immediately after irrigation, compared with moderate watering. This possibly led to a greater upward movement of water drawing the nitrogen away from the roots (Farbrother[3]).

As can be seen from table 9, the best responses were observed where urea or calcium nitrate was applied to cotton before flooding. Sulphate of ammonia was less satisfactory, presumably because it is more readily leached by irrigation water. The results indicated that nitrogen fertil-

Table 9. Cotton yield responses to different nitrogenous fertilizers applied before, during, and after flooding, Giar Res. Farm, seasons 1963-64 and 1965-66

Rate of fertilizer application: 44.5 lb N per acre
Yield of seed cotton in lb per acre

	Time of application of fertilizer relative to irrigation		
	Before	**During**	**After**
1963-64			
Sulphate of ammonia	1,322	1,352	1,673
Calcium nitrate	2,444	1,872	1,431
Urea	1,774	1,531	1,401
S.E.		130	
1965-66			
Sulphate of Ammonia	1,130		1,079
Calcium nitrate	1,864		1,155
Urea	1,670		1,145
S.E.		163	

Sources: Hearn, A.E. (1965). *Prog.Rep.Exp.Stas.Cott.Res. Corp* 963-64. South Arabia. p.12 and Mawly, S. H. *Prog.Rep. Exp.Stas, Cotto.Res.Corp* . 1965-66. South Arabia, p.8.

izer, applied before flood irrigation at the rate of 23 kg nitrogen per acre, is essential for good yields in all areas of the coastal region that are regularly cropped with cotton.

The economic advantage of using nitrogen fertilizer was acknowledged in 1970-71 season, when a fertilizer campaign was launched; 6 000 acres of cotton land were treated with urea at the rate of 50 kg (23 kg N) per acre. However, the continually rising price of fertilizers, which are mostly imported, hindered further commercial application of fertilizers in spate irrigated areas. It is also difficult to predict when lands will be flooded so that fertilizer could be applied before irrigation. A system of field-to-field watering still exists whereby water is collected in fields at a higher level, impounded until the farmer considers watering to have been adequate, then released to a lower field. The higher places usually received too little water whilst the lowest received too much, with consequent loss of plant nutrients by leaching. Cotton or any other crop in the low lying flood irrigated fields characteristically had poor growth and lighter green foliage indicating nitrogen shortage.

The small size of basins and poor land levelling created considerable problems with water management, fertilizer application, erosion and mechanization. This indicates that traditional, spate irrigation will restrict the type of farming as well as the extent of the land and labour used and hence the income of the farmers.

8. Yield spate crops

Field crop production in the coastal region has fluctuated with the availability of flooded land, timing of floods, quantity of flood water and severity of pest infection and its control.

The Seif floods (March-May) only permit the cultivation of a few field crops on a limited area. These crops are melons and sorghum, either as grain-cum-fodder if left till harvest, or green fodder if harvested 50-60 days after planting. However, the Kharif floods (July-September) permit the cultivation of several field crops on a larger area. These crops include the main cash crop (long and medium-staple cotton), sorghum, millet, sesame, melons, and, more recently, groundnuts (*Arachis hypogea L.*) on a limited area.

The crops grown under spate irrigation systems, and their yield, are given in Table 10. It will be noted that the yield per acre of long-staple was fairly consistent for more than three decades. This indicates that recommended agricultural practices, including, planting date, row and plant spacing, fertilizer application, and improved picking, were not followed properly by farmers. Medium-staple cotton gave a consistently higher yield per acre than the long-staple variety, indicating higher yield potential, 4-5 weeks, shorter maturity and reduced costs for irrigation and plant protection. The extra long-staple variety, K4, and the upland medium-staple variety, Coker 100 Wilt, grown commercially at the moment, have little genetic variability and further selection within them is unlikely to produce significant improvement.

Yield per acre of sorghum and millet was variable, ranging from 294 to 482 kg/acre. This variation might be due to the several local cultivars grown, with different yield potentials, and grown at a wide range of planting dates during the two flood periods. Sesamum achieved the lowest yield per acre among all other spate cultivated crops. One reason is that the local commercially grown cultivar has different yield potentials when grown at different planting dates, is sensitive to insect infestation, and shatters a considerable percentage of its grains at maturity. The best planting time, 1-15 February, is not practised under a spate irrigation system because the probability of flooding during this month is very low.

Melons behaved similarly to sesamum; yield fluctuating considerably from one season to another. Major factors influencing yields are: planting date, soil texture, and sensitivity to certain insects and diseases. Yields of groundnuts cultivated recently on a limited spate areas seem to be satisfactory. A single preplanting flood irrigation in light soils makes harvesting much easier, and reduces the loss of pods remaining under the ground.

Respectable yields were obtained for field crops grown under spate irrigation despite lack of fertilizer and pest control, and without following certain crop rotation, or improved cultural practices. A probable explanation might be that soils in spate irrigated areas are highly retentive of moisture, the good quality of spate irrigation water, and deficient seed maintenance systems which maintain the purity of commercial seed issues. However, full yield potentials of spate irrigated field crops were not achieved, and research investigations have indicated that with improved, cultural practices, pest control, and fertilizer application, yields can be increased by 30-50 percent (Table 11).

Table 10. **Average yield, kg/acre, for crops grown during the two flood periods in the coastal region areas**

	Average 25 seasons 1949-50 1973/74	1974-75	1975-76	1976-77	1977-78	Average 8 seasons 1978-79 1985/86
Cotton:						
Extra Long Staple	347	368	386	350	372	361
Medium Staple	-	-	-	395[2]	659	620
Sorghum and Millet	388	482	394	294	324	359
Sesame	233	208	258	148	146	202
Melons	4424	3147	5700	4406	3606	4031
Groundnuts						500

[1] First commercial cultivation of Medium-Staple Cotton in Wadi Tuban Delta

[2] Due to drought prevailing during this season

9. Conclusions

The low and erratic rainfall in the coastal region of PDRY makes the agricultural production without irrigation impossible. Spate irrigation is used on nearly 80 percent of the total cultivated area. These two annual flood periods, March-May (Seif), and July-September (Kharif), producing 83 percent of the average flow of 161 million m per annum (86 millions m and 287 millions m). The cropping seasons correspond to these two periods, and main crops grown are: cotton (extra long and medium-staple)), sorghum, millet, melons, sesame and, more recently, groundnuts.

Spate irrigation, by itself, can produce fairly good yields, but is not without technical and administrative problems. First, it restricts all agricultural activities to two definite periods, thus creating peak labour requirement periods for most of the production facilities. Secondly, the range of crops under cultivation is limited to those which can be produced under a single preplanting flooding. Finally, it restricts the type of farming as well as the extent of the land and labour used, and hence the income of the farmers.

July 15 to September 16 was found to be the best time to irrigate and sow the main cash crop (Extra long and medium staple cotton). The volume of water received outside the maxium allowable cotton irrigation period is almost half the total flow. Used efficiently, this would produce an average acreage of other crops nearly equal to the maximum possible acreage of cotton.

No reliable estimate could be made of the average loss of water to the sea during its floods. However, if effective irrigation control and distribution become technically possible through the completion of major irrigation works and lining of canals, it will be possible to adopt a practicable scheme of progressive watering and cropping in spite of the marked seasonal variations in water supply.

It was demonstrated that the previous year's cotton land should be watered during the period April to September to achieve a high degree of entomological control, specifically against Sudan bollworm.

Application of 60-100 cm of water in a single preplanting irrigation is sufficient for raising all spate irrigated field crops, provided that the moisture holding capacity of the soil is satisfactory. Where a single preplanting irrigation is the main practice, soil should be classified by its moisture holding capacity and available water content. A more rational water distribution system is suggested so that the water table will be lowered sufficiently to allow effective leaching, thus preventing salinity and alkalinity.

Water requirements of the spate irrigated crops grown, are found to be determined by the climatic conditions, and by the length of the inter irrigation period. With a single preplanting irrigation, this period is determined by the intensity of the irrigated area utilization during a year, and cropping sequence. It can vary from 3 to 18 months. Therefore, to secure more efficient use of irrigation water, it is necessary to increase the irrigation intensity, or decrease the frequency of irrigation. Water should be concentrated on areas which were already planted with crops and irrigated twice a year.

The best interval for land preparation after flooding was found to be about 10 days. A prolonged interval results in water loss by evaporation and deep percolation.

Every 2-3 years, the hardpan, induced by continuous flooding in some areas, should be broken by chiselling, to

Table 11. Yield responses (kg/acre) of spate irrigated crops to nitrogen fertilizer and improved cultural practices in the coastal region of PDR Yemen (8 seasons average, 1975/76 - 1982/83)

	Long Seed Cotton	Medium Seed Cotton	Sorghum/ Millet	Sesame	Melons	Groundnuts Shelled Seed
nitrogen at 23 kg/acre and improved cultural practices	546	837	524	300	6130	650
control	364	558	374	199	4227	500
increased yield over control	182	279	150	101	1903	150

a depth of 40-45 cm, using a heavy power unit.

Field experiments in older areas have shown that there was a need for nitrogen fertilizer, but not for phosphate or potash. 23 kg of nitrogen per acre, before flood irrigation, is essential for good yields. With improved cultural practices, pest control, and fertilizer application, crop field yields can be increased by 30-50 percent.

In conclusion, to solve the major constraints of spate irrigation systems, emphasis should be laid on land levelling, field realignment, and the development of a secondary control system to establish more rational water distribution. This will lead to a considerable reduction in soil erosion, enable fertilizer application, the introduction of mechanization, and cover a larger acreage with the available flood water, thus increasing the productivity of spate irrigated field crops.

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