INTEGRATION OF IRRIGATION AND DRAINAGE MANAGEMENT IN A MONSOONIC CLIMATE[1]

O.P. Singh

Head, Division of Drainage and Water Management, Central Soil Salinity Research Institute (CSSRI), Karnal 132001, Haryana, India

Abstract

The present paper describes the nature a of monsoonic climate affecting the irrigation and drainage activities. It has been established that in a monsoonic climate both irrigation and drainage are needed for potential agricultural crop production. In the past the irrigation and drainage systems have been designed, installed and managed independently by different agencies. But, for the efficient performance of irrigation and drainage systems their integration is necessary. Four different aspects (1) Land development for receiving irrigation water and releasing drainage water; (2) Design of irrigation and drainage system components; (3) Operational aspects of irrigation and drainage systems and (4) Institutional aspects of irrigation and drainage management were identified for the integration of irrigation and drainage systems.

Introduction

Irrigation and drainage are the practices which were initially adopted for water deficit and excess water regions for increasing agricultural production. The development of irrigation projects in arid and semi-arid regions invariably led to waterlogging and soil salinity problems in irrigation command areas. This has created the necessity of agricultural drainage to control excess surface water and/or sub-surface water for salinity control in those regions besides the already felt needs in humid regions. Similarly in regions with a monsoonic climate due to the seasonal variability of rainfall irrigation is required for a multi-cropping system adopted to the various seasons of the year. Therefore, both irrigation and drainage are required for arid as well as humid regions with a monsoonic climate. In the past the irrigation and drainage systems were planned, designed and implemented separately and are being managed by different agencies. However, the optimal and sustainable use of irrigated agricultural lands require irrigation and drainage systems to be designed, constructed and managed as an integral unit.

In a monsoonic climate the variability of rainfall is of relatively higher magnitude. To overcome this situation the development of irrigation and drainage projects have taken place at enormous cost for increasing the agricultural production. Irrigation projects provide water for crops in water deficit regions and also maintain the water supply for the crops during dry spells frequently observed in a monsoonic climate. The excess use of irrigation water or rainfall in excess of agricultural water requirements create the situation under which

[1] Due to unforeseen circumstances, the author was not able to present his paper at the symposium

drainage also become an unavoidable proposition. In arid and semi-arid regions with low monsoonic annual rainfall the irrigation may cause worse environmental degradation of valuable soil resources affected by waterlogging and soil salinity problems. The potential gains of irrigation may be offset or reduced if the above mentioned problems are not taken care by providing land drainage along with irrigation. The irrigation and drainage management activities in a combined manner should attempt to narrow down the gaps between the water supply and water requirements of the crops in the project areas without causing environmental problems. The combined performance of irrigation and drainage systems is influenced by many factors which are of an engineering, hydrological, agricultural, or organizational nature. For the best performance and returns it is essential to integrate the management of irrigation and drainage systems in order to function in a harmonious inter-action.

Characteristics of the monsoonic climate

The monsoon rainfall is the primary source of water and dominating single weather parameter affecting salinity and waterlogging problems. There are periods when excess water occurs on the land surface due to surface ponding often combined with waterlogging of the top soil. Since the distribution is not uniform throughout the year, the canal irrigation water used during dry period also contributes towards the development of waterlogging because of the deep percolation losses. The monsoon rainfall always has a seasonal rhythm in which the rainfall exceeds the evapotranspiration only for 2-3 months of rainy season. During this period the groundwater table tends to be high and critical for the crops. During this period some control is desirable to prevent continuous flooding and severe waterlogging of the crop root zone. The rainfall distribution characteristics of varying magnitude and duration of rainfall storms are such that the amount of rainfall in a consecutive period of several days can be too heavy (Rao et al., 1994) for the watertable to be controlled below the soil root zone (Table 1). In such a situation, much of the rain which is unable to infiltrate into the soil needs to be discharged over the surface, requiring the provision of surface drainage in addition to the installation of a sub-surface drainage system.

Table 1. Rainfall intensity and dry spells of different return periods

Particulars	Return period, years					
	1.01	2.33	5	10	25	100
Maximum one day rainfall, cm	4.1	12.0	15.2	16.3	22.1	28.9
Maximum two days rainfall, cm	5.1	15.5	20.1	23.8	28.5	35.5
Maximum three days rainfall, cm	6.1	17.1	21.9	25.8	30.7	38.1
Maximum four days rainfall, cm	6.7	17.9	22.8	26.8	31.8	39.4
Maximum dry spells in monsoon season, days	15	28	34	39	45	54

In a monsoonic climate and in an area with severe waterlogging, the watertable remains very close to the surface during rainy season. The observations from several places have indicated that during driest period the watertable may recede beyond 2 m. The lowest watertable depths reached were not affected by subsurface drainage installation at about 1.5 m depth whereas the subsurface drainage influenced the position of shallow watertable depth during rainy season (Singh and Maraviya,1988). For the monsoonic climate, the design drainage rates are to be selected in such a way that the drainage aims are fulfilled for all the seasons. These aims are to obtain and preserve favourable conditions for plant growth and farm management by (a) avoiding too wet conditions during the rainy season, (b) obtaining workable conditions shortly after a rainy period, (c) maintaining the watertable at a proper depth during the *rabi* season between irrigation cycles, and (d) controlling salinity during dry off season after the *rabi* harvest.

Integration of irrigation and drainage management

The concept of integration of irrigation and drainage management can be applied with respect to four different aspects (1) Land development for receiving and releasing drainage water (2) Design of irrigation and drainage system components (3) Operational aspect of irrigation and drainage systems and (4) Institutional aspect of irrigation and drainage management.

Land development for receiving and releasing drainage water

The ultimate impact of integration of irrigation and drainage management is to be seen on the efficient utilization of irrigation water in order to reduce drainage loads or quick removal of the excess water from the agricultural fields. To fulfill this objective the land development and shaping are the most important activities. The land development and reshaping activities can be planned in such a way that on one side they are helpful for uniform and efficient application of irrigation water in desired quantity (Tyagi and Joshi, 1995) and on the other hand it is helpful for quick removal of surplus surface water at the time of excessive rainfall without causing high waterlevel built up which is very common in a monsoonic climate. The activities which can be helpful for integration of irrigation and drainage system management include reshaping of the fields, grading, bunding, layout of irrigation and drainage channels with their proper linkage.

The uniform and efficient application of water achieved in a well-graded field having proper border length and width according to available stream size of the water supply can be helpful in reducing the drain outflow and in effective leaching of the salts from the root zone. The location and layout of the irrigation and drainage channels along with their discharge carrying capacity is important in order to bypass the excess irrigation water during rain storms when it is not possible to close down the canal irrigation water supply all of a sudden. Bunding of the agricultural field is helpful for reducing the peak surface runoff rate and increasing the ground water recharge which can be utilized during lean monsoon months in the form of groundwater resource.

Design of irrigation and drainage system components

Drainage is required in many irrigated, arid lands to prevent rise of the watertable, waterlogging, and salinity build-up in the soil. The history of irrigated agriculture is replete with failures caused by the lack of adequate drainage to prevent salinization of the soils. Drainage to control salinity is, by definition, intended to remove salt, and will usually have a negative impact on the quality of receiving waters. The amount of salt removed depends on irrigation methods and management as much as on the drainage system. Hence the design of irrigation and drainage system should be considered as a unit rather than as individual systems.

Irrigation practices have direct effects on the watertable and the drain spacing is dependent on excess water applied and rainfall. Thus on-farm irrigation and drainage practices are mutually inter-dependent. For the integration of the drainage and irrigation system, it is necessary that the components of both the systems are designed and installed in the field keeping in view their inter-dependency. The aspects which are to be considered to fulfil these objectives are as follows:

Controlled drainage design to act as sub-irrigation

The soil moisture management by watertable control is popular in humid regions where ground water quality is generally good. But in arid irrigated regions also it is observed that after a few years of installation of subsurface drainage, the quality of shallow groundwater table is improved and the shallow watertable maintained by controlled subsurface drainage can contribute towards irrigation requirement of the crops. Because of the characteristics of the monsoonic climate with considerable variability in rainfall during long as well as short periods of time, their is need for drainage during excess rainfall and for irrigation during periods of drought. For soils with a shallow watertable depth this can be achieved using gravitational drainage cum sub-irrigation systems.

The controlled drainage at different watertable depths to fulfil the irrigation requirement of different crops can be managed by providing waterflow controlling devices in the drainage channels which can be operated as and when required. To reduce the cost of system, the depth of the drainage pipe can be designed to control the shallow watertable in the desired range of watertable depth.

During the design of the sub-surface drainage cum sub-irrigation system provision can be made for:

Controlled drainage

Controlled drainage technique is applicable in small areas with very limited water resource. The main advantages of such a technique are the low cost because only one control structure in the drainage ditch needs to be constructed and this kind of water management technique is easy to perform in the field. The main disadvantage is that during very dry periods it is not possible to maintain the groundwater level at the desired position (Brandyk et al., 1993).

Sub-irrigation with a constant waterlevel

Sub-irrigation with a constant waterlevel is based on keeping the groundwater level at a position which is close to its optimum value, by the proper maintenance of the open waterlevels in the ditch network using control structure. This practice can be used for such soils where it is possible to assess the optimal groundwater level which guarantees both the required air content in the root zone during periods of excess rainfalls as well as sufficient capillary rise during periods of drought. For removal of the annual salt build up some amount of leaching and drainage is also required.

Sub-irrigation with a regulated waterlevel
Sub-irrigation with a regulated waterlevel assumes the groundwater level changes according to weather conditions by rapid open waterlevel changes in the ditch-drain network. It is possible to implement this technique and is recommended for soils which require groundwater level changes under changing weather conditions. In a monsoonic climate changes in waterlevel in the drain network are very common.

Irrigation methods and drainage
The irrigation methods have a definite influence on the subsurface and surface drainage. The flood irrigation affects the drainage effluent in terms of discharge rate and water quality.

From a water quantity aspect, the flood irrigation event triggers a considerable jump in the discharge rates of the drains not only underlying the land receiving the flood irrigation but also adjacent drains.

The shallow groundwater is likely the primary determinant of drainage effluent quality. The ratios of drainage effluent and irrigation water show a relatively large increase in the concentrations of Na, HCO_3, SO_4, NO_3 and a decrease of the cations Ca, Mg and K.

The modern methods of irrigation water application like sprinkler and drip, have been proved to be effective in reducing the drainage outflow to a considerable extent. Their use in a saline environment is favoured where there is a problem of disposal of drainage effluent. The drip irrigation method has an added advantage of enabling the use of poor quality water and of reducing the drainage effluent load. The design of the system can be made in such a way that part of the drainage water can be recycled for irrigation application. An in-built monitoring system of the salinity development is required to control the fraction of drainage water reuse, so that salinity may not increase beyond a critical limit. In arid regions with a monsoonic climate, particularly during the months of summer, a situation rises where salinity and waterlogging and shortage of water for irrigation is very common. This situation can be tackled only by proper integration of irrigation and drainage system management.

The degree of drainage and irrigation needs
The drainage degree by surface and subsurface drainage methods have an important bearing on the irrigation system. In surface drainage system it is generally used for managing surface run-off generated by heavy rain storms. It can be influenced by rain water management in the agricultural fields. The storage of rain water in the agricultural field to the extent that it does not create any harm to the crops is beneficial for reducing the irrigation requirement. It is also helpful for improving the ground water recharge in the areas with deep groundwater table depths, thus helping in the better discharge from tubewells for irrigation purposes. The surplus water from the areas where deep aquifers have the potential to receive the excess water can be made available for groundwater recharge, thus reducing the surface drainage load. Design of drainage system can be made compatible to irrigation needs of the region.

Skimming wells for drainage and irrigation
Skimming wells serve the purpose of controlling shallow watertables in the regions where the quality of shallow water is fit for irrigation. In the coastal regions where deep waters are saline and fresh water is available only in upper thin layers, the skimming wells serve as very effective means of controlling subsoil water and at the same time making available good

quality water for irrigation purposes. The design of skimming wells can be made to fulfil both above requirements.

Operational Aspects of Irrigation and Drainage Systems

Controlled-drainage is an important operational mode of the "total" water management system. Proper and timely control of subsurface drainage effluent can: (1) reduce the duration of excess soil-water conditions in the root zone caused by rainfall, (2) prevent over-drainage of the soil profile for more efficient use of naturally occurring rainfall, and (3) reduce the need for pumping sub-irrigation water. In geographic areas where a water source for sub-irrigation is not readily available, and for specific soils, properly designed and managed controlled-drainage systems can optimize crop production by efficient utilization of available rainfall. Controlled-drainage also has the potential to reduce the accumulative losses of plant nutrients carried in drainage effluent, and reduce the potential for ochre formation in the drainlines since they are submerged much of the time. Controlled-drainage can be used in humid regions rather than conventional subsurface drainage with "free" gravity flow or continuously pumped outlets.

In regions where drainage outlets are not available, the salt concentration is increased by evaporation. Such detrimental effect can often be avoided by making sure the reliable drainage outlet exists or is developed prior to construction of irrigation projects.

Leaching of salts

The leaching of salts from the rootzone is directly affected by irrigation and sub-surface drainage. For the reclamation of saline and waterlogged soil during the initial stage excess irrigation is needed for initial leaching of salts. This leads to additional drainage load for the sub-surface drainage system. After initial removal of the salts the leaching is needed only for removing the salts added each year during crop production by irrigation water or by the capillary movement of the ground water. The capacity of an integrated irrigation and drainage system should be such that they can be operated for handling the different water discharges.

Reuse of drainage water

With limited availability of water resources during certain months of the year in the monsoonic climate or in areas where drainage outlets are not available or have limited capacity, the reuse of drainage water is considered as one of the solutions. The design of drainage system has to be integrated with the irrigation system so that different fractions of drainage water can be used for irrigation purposes in a mixing mode or cycling mode. The fraction of drainage water to be used for irrigation will depend upon the assessment of the water quality in relation to crop tolerance limit for saline water and relative quantities of irrigation and drainage water to be used for irrigation..

Institutional aspects of irrigation and drainage management

In many countries, the irrigation and drainage activities are handled by two or more different agencies. Under such situations, the management decisions sometimes become contradictory to each other, resulting in a conflicting situation. The activities related with design, installation, management and operation of irrigation and drainage systems should be controlled by a single agency in order to get the advantage of integrated irrigation and drainage management.

Conclusion

In a monsoonic climate with short and long term variability and cyclic nature of rainfall, both the irrigation and drainage are needed for optimum crop production and sustainability. During different months of the year the irrigation and drainage needs are highly variable. In such a situation the integration of irrigation and drainage systems management becomes absolutely necessary. The concept of integration of irrigation and drainage management can be applied on four different aspects (1) Land development for receiving and releasing water (2) Design of irrigation and drainage system components (3) Operational aspect of irrigation and drainage systems and (4) Institutional aspect of irrigation and drainage management. The management either of irrigation or drainage directly or indirectly affect each other. The land development activities need to be carried out in such a way that they meet out the optimum performance requirement of both irrigation and drainage systems. Similarly, the design of irrigation and drainage system components are to be made with their mutual compatibility. The operation of irrigation and drainage system are to be managed for maintaining optimum conditions in the agricultural fields for optimum crop production. It is advocated that irrigation and drainage activities should be handled by a single agency for efficient management of irrigation and drainage systems.

References

Brandyk T., Skapski K. and Szatylowics J. (1993). Design and Operation of Drainage Sub-irrigation Systems in Poland Irrigation and Drainage Systems 7: pp. 173-187

Rao D.L.N., Singh N.T., Gupta R.K. and Tyagi N.K. (Eds.,1994). Salinity Management for Sustainable Agriculture. Central Soil Salinity Research Institute, Karnal, India pp. 101-123.

Singh O.P. and Maraviya R.B. (1988). Design Criteria for Sub-surface Drainage Systems in Monsoon Type of Climatic Conditions, National symposium on management of irrigation system, CSSRI., Karnal, India Feb., 24-27, pp. 169-176.

Tyagi and Joshi (1995). Irrigation Management for Drainage Volume Reduction. Proceedings of the national seminar on Reclamation and Management of Waterlogged Saline Soils, CSSRI., Karnal, India pp. 160-175.

Session 4 Formulation of research needs in irrigation and drainage that promote integration of irrigation and drainage management and contribute to a sustainable water, salt, and financial balance

Chairman: Ir. E.H. Kloosterboer (ILRI)
Sub-group facilitators: Ir. A.M.J. Jaspers, Ir. R.A.L. Kselik, Ir. G. Naber, Ir. H.P. Ritzema, Dr.ing. W.F. Vlotman and Ir. R.B. Vonk (ILRI)

Formulation of research needs in irrigation and drainage that promote integration of irrigation and drainage management and contribute to a sustainable water, salt, and financial balance

C. de Jong

International Institute for Land Reclamation and Improvement (ILRI), P.O. Box 45, 6700 AA, Wageningen, The Netherlands

Research needs for arid areas

1. Research on the physical and economic **effects of waterlogging and soil salinity** in order to sustain appropriate drainage development

2. The need is great for research on **minimization of irrigation losses**. The following topics should be investigated carefully:
   - possible water savings from **integrated management of irrigation and drainage**
   - the economic effects of **canal lining** to reduce water losses
   - the extent of water saving, and the agronomic and economic effects of **re-use of drainage water** of varying salt concentrations
   - the effects of various **drainage designs** on irrigation efficiency
   - the effects of various **water pricing** systems on irrigation (and drainage) efficiencies
   - the effects of various degrees of **autonomy and accountability of the organizations** involved in operating and maintaining water management systems on the quality and the cost-effectiveness of scheme **operation and maintenance** and, consequently, on irrigation efficiency and the reduction of drainage effluent.

3. Research on the sustainability of **large-scale irrigation systems** under various conditions, with the use of predictive models.

4. Research on the role of integrated irrigation and drainage management in maintaining **water and salt balances**.

5. Research on the role that **drainage management** can play in improving the unequal distribution of irrigation water.

6. Research on the conditions necessary for the successful implementation of **service-oriented** (integrated) irrigation and drainage management.

7. Research on **farmers' perceptions** of irrigation and drainage, to improve **communication** between suppliers and users of irrigation water, and to facilitate the introduction of **farmers' participation** into project management.

8. Research on **appropriate project designs** (and unit sizes), to facilitate farmers' participation in project operation and maintenance.

9. Research on possible improvements in the **conjunctive use** of surface water and groundwater, to provide irrigation water efficiently while controlling groundwater levels.

10. Research on **groundwater use** is urgently required. This research should include the following topics: the interaction between streams and aquifers; water quality; the possibility of artificially recharging the aquifer; sustainable rates of withdrawal. To improve **protection of available groundwater resources**, and to facilitate the introduction of adequate legislation on water resources, predictive models should be developed of the long-term impact of the unbridled exploitation of groundwater, and of the on-going pollution of the aquifers.

11. Research on the reduction and eventual **disposal of drainage effluent**, with special emphasis on:
    - simultaneous improvement of irrigation and drainage management
    - the possible contribution of the re-use of drainage water
    - the technical and economic feasibility of evaporators and evaporation ponds
    - the technical and economic feasibility of cultivating salt-tolerant crops and trees.

12. Research on the **incorporation of environmental costs and benefits** into the evaluation of water management projects.

Research needs for humid areas

1. Research on the technical and economic **feasibility of dual-purpose canal** systems for evacuating excess drainage water in the wet season, and for (supplementary) irrigation in the dry season.

2. Research on technical solutions to the problem of **storing excess water** in the wet season for use in the dry season. (Examples: cascade irrigation in Sri Lanka; horizontal drainage of sandy soils in India.)

3. Research on the benefits of introducing **service-oriented management** into (dual-purpose) irrigation and drainage systems.

4. Research on **broadening the criteria** for **designing irrigation and drainage systems** in problem soils (peat; acid sulphate soils; sodic soils), with a view to the specific characteristics of such soils.

Finally, the approximately one hundred participating experts from all over the world were urged to **continue rethinking their concepts** of irrigation and drainage development and management, taking into account the **interests and 'perceptions' of the various groups of farmers**.

To ensure that ILRI's future research activities will target generally accepted research needs and will not overlap the activities of other organizations, due attention will be given to the research needs that have been formulated already in recent international fora for related issues.