Chapter 1

Introduction

Rainfed agriculture in India extends over 94 M-ha that constitutes nearly 70% of the net sown area that remains under cultivation during monsoon season (June-September) but during winter season (October- January) most of the areas lie barren due to lack of supplemental irrigation facilities. In eastern India, rice (*Oryza sativa L.*) followed by mustard (*Brassica juncea L.)* are the two predominant crops grown in monsoon and winter seasons, respectively (Ghosh *et al.*, 1978; Panigrahi and Panda 2003a). The area under rainfed rice in eastern India is about 67% of the country's total rainfed rice area. With the present population growth rate, the productivity of rainfed rice of the region has to be raised from the present level of 800 to 2000 kg ha^{-1} by the end of 2020 (CRIDA, 1995). Thus, the fate of the millions of farmers in the rainfed ecosystem can be greatly improved by adopting the effective rainwater conservation and management practices.

Eastern India is bestowed with ample rainfall resources with average annual rainfall of 1500 mm, 80% of which is concentrated during monsoon season. During this period, about 50% of the annual rainfall comes from a few intense storms (Pisharoty, 1990). The spatial and temporal variability of rainfall create situation like surface flooding that causes a lot of soil and nutrient erosion on one hand and at the other, water scarcity at the critical crop growth stages (Widawsky and O'Toole, 1990). Majority of farmers in the region have no well-defined irrigation and drainage systems and they advocate plot-to-plot method of irrigation and drainage. Conventional water management in the rice cultivation aims at keeping the fields continuously submerged. But, excess ponding causes nutrient imbalance and reduction in yield. Thus excess ponding water during initial and harvesting stages of crop growth are drained out by cutting the dykes of the rice fields. This causes inundation problem of rice and complete damage of seedlings and matured crop in low lands downstream. Experiments conducted with different water saving irrigation (WSI) techniques in various regions demonstrated that continuous submergence is not essential for increasing rice yields (Hatta, 1967; Khepar *et al.*, 2000), whereas irrigation to rice at near saturation gives comparable yield with continuous submergence and saves a substantial amount of water (Hukkeri and Sharma, 1979; Singh and Singh, 1989). Zeng, *et al.* (2003) reported that rice plants performed better with respect to seedling establishment and grain yield in shallow water (*i.e.* <10 cm) than in deep water (*i.e.* >10 cm). So, depth of water in the rice field can be minimized with proper weir height, which is the deciding factor for conservation of rainwater, sediment and nutrients in the rice field; controling of declining ground water table; and improvement in rice yield (Mishra *et al.*, 1998; Toung and Bhuiyan, 1999; Khepar *et al.*, 2000).

In the recent years, several researchers have advocated the use of on-farm reservoir (OFR) system to alleviate drought in rainfed areas. The role of water harvesting systems is to provide life saving irrigation to low duty crops in monsoon season and if possible one or two irrigations to raise another crop in the following winter season (Verma and Sarma, 1990a; Subbaiah, 1991; Jensen *et al.*, 1993; Panigrahi and Panda, 2003; Panigrahi *et al.*, 2005; Roy *et al.*, 2009). Syamsiah *et al.* (1994) have reported that many small land holders in Indonesia prefer to construct the OFRs in their individual farms so that they can use it for rice, vegetable and fish production. The OFR system is cost effective as reported by Islam *et al.* (1998) for Bangladesh; Syamsiah *et al.* (1994) for Indonesia; and Panigrahi (2001) and Sethi *et al.* (2005) for India. The integrated rice-fish farming system is already well developed in China, Taiwan, Malaysia and certain other European countries (Hickling, 1960; Delmendo, 1980; Dhawan and Sehdev, 1994), whereas little attention has been given in India. Hence, the rearing of fish varieties in the OFR with the harvested rainwater may be considered for increasing the agricultural productivity of rainfed ecosystem. Though the practice of rainwater storage in the OFR is quite common but still there is a need to study the scope of the OFR (lined/unlined) system with different weir heights for integrated rainfed farming system.

A fundamental part of understanding and improving water management in rainfed agriculture is quantification of different field water balance components that can be used effectively for rainwater management to increase agricultural productivity and to harvest the excess rainwater in the OFR. The water balance components can be quantified theoretically as well as experimentally in the field (Angus, 1991; FAO, 1984). The development of field experimental set-up is excessively time consuming with high cost of initial investment. Therefore, a simulation modeling by daily water balance is an appropriate alternative to understand the water use as well as irrigation and drainage requirements of the crops. The said approach is increasingly being used as an alternative to develop appropriate strategies for the efficient management of water resources for sustainable production and to transfer the results for multi-location trials in farmer's field (Jones and Thorton, 1993; Panigrahi and Panda, 2003a).

Field water balance cannot be achieved if evapotranspiration and surface runoff are taken as the only losses (Walker and Rushton, 1984; Bouman *et al.*, 1994; Tuong *et al.*, 1994; Wopereis *et al.*, 1994). However, the vertical percolation (VP) below the root-zone depth and lateral seepage (LS) through the field dykes are also the possible losses (Walker and Rushton, 1986; Huang *et al.*, 2003). Water loss due to VP and LS is often inseparable and considered as a single component (Wickham and Singh, 1978). The VP and LS in the field are extremely variable that depend on saturated condition of the soil and ponding depth. Models available for quantification of VP and LS under ponding condition cannot be used in the field under variably saturated soil (Mishra, 1999; Khepar *et al.*, 1999). So, there is need to quantify the VP and LS from the effective root-zone of cropped field.

Few simulation models such as IRRIMOD (Angus and Zandstra, 1980), PADDY WATER (Bolton and Zandstra, 1981), SWATRE (Belmans *et al.*, 1983), SAWAH (ten Berge *et al.*, 1992), FEMWATER (Lin *et al.*, 1996) and HYDRUS-2D (Simunek *et al.*, 1999) are available to simulate water flow processes between the soil surface and the groundwater table (Hutson, and Wagenet, 1995; Warrick *et al.*, 1997; Izbicki *et al.*, 2000; Henry *et al.*, 2001; Ritter *et al.*, 2003; Rezzoug *et al.*, 2005; Miller *et al.*, 2007). In this direction, two-dimensional HYDRUS-2D (Simunek *et al.*, 1996 and Simunek *et al.*, 1999) model has been used to quantify the water and solute transport in variably saturated condition (Simunek *et al.*, 1998 and Pang *et al.*, 2000). Among the simulation models, HYDRUS-2D is a rather simple for simulating the water and solute transport under variable saturated conditions (Inoue *et al.,* 2000; Simunek *et al.*, 2003; Phillips 2006; Mortensen *et al.,* 2006). HYDRUS-2D, therefore, can be used for quantification VP and LS from the cropped fields under variable saturated conditions.

In India, the use of the OFR is an age-old practice. But its design is based on thumb rule using some mathematical equations or by the local experience. A number of researchers have used the simulation model, combining the crop field and the OFR water balance, to determine the size of the reservoir necessary to ensure the availability of water under uncertainty of irrigation water demand (Palmer *et al.,* 1981; Verma and Sarma, 1990b; Srivastava 1996a; Srivastava, 2001). However, most of these OFRs are designed to supply supplemental irrigation (SI) either to a single or multiple crops without considering integrated farming of rice-mustard and fish in the lined and unlined OFRs. Hence, hydrologically and economically viable lined and unlined OFR sizes with different weir heights for sustainable production of rice, mustard and fish in the rainfed ecosystem need to be studied.

Keeping the aforementioned issues in view, the present study has addressed the following objectives:

- Quantification of vertical percolation and lateral seepage in the cropped field under ponding and variable saturated conditions.
- Development of water balance simulation models for the cropped fields (rice and mustard) and the on-farm reservoirs (lined and unlined) with different weir heights to study the scope for integrated rainfed farming system.
- Determination of hydro-economically viable on-farm reservoir size for sustainable production of rice, mustard and fish in the integrated rainfed farming system.