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Comparative economic analysis of inter-crop based conservation bench terrace and conventional systems in a sub-humid climate of India

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ABSTRACT

Economic performance of two land configuration systems, namely conservation bench terrace (CBT) and conventional (sloping borders), were evaluated through an experimental study conducted during 1997–2005 in a sub-humid climate of India. Energy use efficiencies of the two systems were also evaluated. The two systems were cultivated with maize + cowpea in rainy season followed by wheat + mustard in dry winter season. For CBT, an additional intervention of rice cultivation was done during rainy season in its recipient area. Mathematical relationships were established between seasonal and effective rainfalls as well as between effective rainfall and crop equivalent yields. These relationships were then utilized for evaluating economic efficiency of various combinations of the two inter-crop based land configuration systems. Excess runoff from the combinations was considered as rainwater harvested into a common tank for recycling as supplemental irrigation during intervening dry spells in the rainy season and the remaining during dry winter season. In this way, the best combination for inter-crop based systems adoptable to a region experiencing rainfall uncertainty i.e. regular intervening dry spells was identified. Sensitivity analysis was carried out to analyze response of the combinations to changes in economic parameters. Based on the analysis of experimental data, net present value of CBT system was observed to be 56% higher than the conventional system due to higher average crop equivalent yields. Net energy return, energy ratio and energy profitability of CBT system were higher by more than 100% as compared to conventional system, thus indicating better energy use efficiency. Benefit–cost analysis of the system combinations under different rainfall probabilities suggested that a combination with higher proportion of CBT will be more remunerative. However, the 75:25 (CBT:conventional) combination was observed to be the best for minimizing risks associated with erratic rainfall at all probability levels. Sensitivity analysis of various combinations indicated that CBT predominant combinations will be least affected by changes in considered economic parameters. From the study, it was concluded that adoption of 75:25 (CBT:conventional) combination can be recommended for sustaining crop productivity by generating sufficient runoff for harvesting and its subsequent recycling as supplemental irrigation during both seasons on mildly sloping lands in sub-humid climates.

1. Introduction

Efficient management of water is an essential pre-requisite for higher agricultural productivity that leads to augmentation and sustenance of production. Globally, 78% of increase in total crop production during 1961–1999 was due to boost in agricultural productivity (Bruinsma, 2003). It was partly attributed to expansion of irrigated areas (FAO, 2007) which increased from 142 to 271 million ha during 1961–1999 (Bruinsma, 2003). It is still challengingly increasing due to population growth and rising income levels, which have augmented demand for water intensive agricultural commodities (Molden, 2007; Falkenmark, 2007; De Fraiture and Wichelns, 2010). In India, agriculture sector is the largest (85%) consumer of water (Datt and Nischal, 2010), and more than 80% of total future water demand projections are for use by this sector (Chopra et al., 2003). Gross irrigation water demand in 1990 was 460 km^3,

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which is expected to reach 628 km^3 under low growth scenario and 807 km^3 under high growth scenario by 2050 (NCIWRD, 1999). Whatever the estimates, total water availability is fixed for its ever increasing second largest population. Consequently, it is heading towards chronic blue water (water available in rivers, lakes, wetlands and aquifers) shortage (<1700 m^3 per capita per year) to meet its food water requirements by 2050 (Rockström et al., 2009).

Water shortages seem inevitable with unabated irrigation as well as industrial and domestic water demand growth. Further aggravation in future due to excessive pollution, over exploitation or climate change impacts is unavoidable. Addressing the problem through supply side infrastructure-intensive solutions encompass challenging externalities. Evaluation of proposed river linking programme of India with five criteria distilled from diverse criteria indicated poor scoring in all criteria (Gupta and van der Zaag, 2008). Instead, a demand driven approach that conserves water for enhancing localized supply and entails its judicious use is required to tackle India's steadily worsening water-related problems (Datt and Nischal, 2010). More so, as water and land are best managed locally (Chopra et al., 2003). Green water resources (i.e. infield rainfall, naturally infiltrated rainwater and harvested local runoff) can keep India potentially self-sufficient [total (i.e. blue plus green) water availability >1300 m^3 per capita per year] till 2050 if green water is carefully managed (Rockström et al., 2009). Further, adaptation to changed local water resources conditions is as important as availability of freshwater resources (Pandey et al., 2011). In rainfed areas, rainwater harvesting can generate locally available water resource, which can be self managed by farmers.

The potential of supplemental irrigation from locally stored surface runoff in small reservoirs to global cropland areas to increase crop evapo-transpiration (or green water flow) ranges from 9.5% to 18% of total green water flux from all cropland area. Supplemental irrigation of existing cropland areas from a medium variant of reservoir capacity can increase cereal production by ~50% in Africa and Asia (Wisser et al., 2010). In terms of transpiration efficiency (i.e. green water use over availability), India has an enormous potential to boost food production (Rockström et al., 2009). Utilization of harvested rainwater for supplemental irrigation in Indian rainfed areas has reported yield increase by 119–485%, depending upon crop and soil conditions (Samra and Sharda, 2006). Positive impacts of supplemental irrigation from on-farm water harvesting structures, on enhancing crop productivity and their economic viability have been well reported across different agro-ecological regions of India (Samra et al., 2002; Sharda and Ojasvi, 2005; Yadav et al., 2006; Arya and Yadav, 2006; Narayan and Biswas, 2012; Pande et al., 2012).

Rainfed agriculture has tremendous potential to augment food production, if substantial investments in water harvesting, agricultural research, supporting institutions and rural infrastructure are made (De Fraiture and Wichelns, 2010). Dichotomy between irrigated and rainfed agriculture is now reduced as they are difficult to separate (Rockström and Barron, 2007). Irrigated agriculture is partly dependent on infiltrated rain, and rainfed agriculture is being increasingly supported by supplementary irrigation for dry spell mitigation. Therefore, future development solutions would be found as techno-feasible tradeoff between two extremes of purely irrigated and purely rainfed agriculture (Falkenmark, 2007). System innovations along these lines are solutions to achieve productivity rise, as reported for southern and sub Saharan Africa, where to offset impact of dry spells, four different system innovations indicated significant scope to increase maize grain yields with little available rainfall (Makurira et al., 2011).

Rainwater use efficiency can be significantly improved through runoff water harvesting structures and appropriate water conservation measures across the slope. There are several best management practices for conserving rainwater which otherwise results into inevitable runoff causing soil erosion. It further leads to loss of fertility, lowering of water holding capacity and disruption in nutrient cycle of the soil (Sharda, 2011). Among structural measures, the conservation bench terrace (CBT) system is an innovative land configuration measure that harvests rainwater generated as surface runoff from a sloping donor catchment (left in its natural slope) and impounds runoff on leveled portion of the same land (recipient area). The two components of CBT system, i.e. donor and recipient areas are used for cultivation of crops having diverse water requirements. Runoff in excess of impoundment can be stored and recycled for providing supplemental irrigation during intervening dry spells or providing initial life saving irrigation to winter crop. CBT system has been hydrologically evaluated on mildly sloping lands (<4%) under varying soil, crop and climatic conditions for water conservation, erosion control and enhancing crop productivity in arid, semi-arid and sub-humid climates of the world (Hauser, 1968; Michelson, 1968; Black, 1968; Cox, 1968).

In India, the CBT system was extensively tested for rainfed areas in semi-arid regions at Bellary (Sastry et al., 1975) and Kota (Prakash and Verma, 1984), and in sub-humid region at Dehradun (Bhushan, 1979; Sharda et al., 2002, 2003). At Dehradun, a 3:1 mono-crop based CBT system, comprising of sole maize in rainy season followed by sole wheat in winter season with rice during rainy season in the recipient area of CBT system was found effective in improving productivity by over 19% in terms of maize equivalent yields as compared to conventional system (sloping border) (Sharda et al., 2002). With an aim to further economize the system and reduce runoff and soil loss, an experiment on inter-crop based CBT system comprising of maize + cowpea in rainy season followed by wheat + mustard in dry winter season with rice during rainy season in recipient area of CBT system was conducted during 1997–2005. The conventional and CBT systems were evaluated in terms of runoff, soil erosion, and crop productivity. CBT system was observed to be effective in reducing runoff and soil loss drastically by about 80% and 88%, respectively as compared to conventional system. An additional yield gain of 18% was observed over the conventional system in terms of maize equivalent yields (Sharda et al., 2013).

Although a number of studies have been conducted to evaluate the CBT system hydrologically, its economic assessment, in terms of tangible and intangible benefits, still have not been adequately reported or compared with conventional system. In a sole attempt to characterize the economics of CBT system, Sharda and Dhyani (2004) observed that CBT system exhibited 58% higher net present value compared to conventional system. However, economics of CBT system over the conventional system for inter-cropping system vis-a-vis mono-cropping system have not been evaluated as yet.

Economic evaluation of CBT and conventional systems cultivated with different cropping systems in a given agro-climatic region can help in selecting an appropriate cropping system which can provide higher profitability besides resources conservation. Further, to make cultivation of cropping systems adoptable in a region having regular intervening dry spells, suitable combinations of the two systems in areal units, i.e. CBT (for water conservation and productivity) and conventional (for surface runoff generation for harvesting and recycling as supplemental irrigation), need to be economically assessed for evolving alternatives conforming to a targeted production and economic goals while considering uncertainty in rainfall incidences. The present study, therefore, is focussed towards addressing the above issues by analysing the tangible (crop yield) and intangible (soil loss) benefits of inter-crop based CBT and conventional systems. The inter-crop based systems were also compared with the mono-crop based systems considering all economic measures of benefit cost analysis. Attempt has also been made to establish an ideal quotient in areal units involving the two systems for utilizing trade off between water resource