Water Productivity and Income

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10.1 Introduction

Food security and reducing poverty for the ever-growing population in India is a challenging task. India's agricultural land is 142 million ha with 135% cropping intensity (NAAS, 2009) and 60% is rainfed, which is characterized by water scarcity, land degradation, low use of inputs and low productivity. Agricultural productivity of these areas oscillates between 0.5 t/ha and 2 t/ha with an average of 1 t/ha (Rockström *et al.*, 2010; Wani *et al.*, 2011a, b). Of the total agricultural area, the 40% that is irrigated land contributes 55% of total food production in the country (GoI, 2012) but on the other hand it consumes almost 70% of freshwater resources and has left limited scope for further expansion of the irrigated area (Central Water Commission, 2005; CGWB, 2012). Thus, achieving food security of the country at present and in the future is largely dependent on rainfed agriculture (Wani *et al.*, 2009, 2012a). Despite several constraints and limitations of rainfed areas, huge untapped potential exists for enhancing crop yield through improved land, water, nutrient and other natural resource management options (Rockström *et al.*, 2007; Garg *et al.*, 2012a, 2013; Wani *et al.*, 2012a; Singh *et al.*, 2014).

Karnataka, in southern India, covers nearly 70% of the total cultivable area under rainfed conditions and is the second largest rainfed

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state after Rajasthan (NRAA, 2012). Agriculture and allied sectors' contribution to the gross domestic product of the state of Karnataka was about 17% in 2009/10 (Wani *et al.*, 2013). Poor investment capacity, financial structures and extension support are the major reasons for keeping rainfed farming at the subsistence level in the state (Rockström *et al.*, 2010). Further, land fragmentation with the burgeoning population is adding to the problem, consequently land share and livelihood opportunities are reducing (Wani *et al.*, 2011a, b). In addition, poor land and water management practices along with exploitation of available natural resources over the years, coupled with the rainfall pattern and climate variability, has contributed to poor agricultural growth in the state.

A large section of the rural population in the state is dependent on agriculture and allied activities. The rural population in the state is largely suffering with various internal and external stresses/shocks such as: (i) weather/climatic variability (drought, flood); (ii) pest and disease infestation; (iii) market failures; and (iv) health-related stress (GoI, 2010). Upcoming challenges such as global warming and climate change bring further uncertainty on available resources and increased risk in the agricultural sector (Boomiraj *et al.*, 2010). It is estimated that a geographical area of approximately 3 million ha in Karnataka is being shifted from the subhumid tropics to the semi-arid tropics, which shows the increasing water stress situation in the region (Rao *et al.*, 2013). Therefore, science-led interventions need to be scaled up in millions of farmers' fields to address current and future food security challenges, rural livelihood, employment and sustainability of the system.

The Government of Karnataka started the innovative and large-scale mission-mode project called 'Bhoochetana' in 2009 with the help of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and its partners. This programme not only focused on soil, nutrient, land and crop management practices but also strengthened institutional capacity through regular capacity- and awareness-building programmes for various stakeholders. Bhoochetana was initially aimed at increasing the productivity of rainfed agriculture using an integrated approach. After realizing the potential of this approach, the programme expanded to irrigated agriculture within a short period of 2 years. Soil fertility assessment has been undertaken as an entry point activity and crop-specific soil-test-based fertilizer application was recommended at the taluk level as against the blanket recommendation followed earlier at state level as there was indiscriminate use of fertilizer both in rainfed and irrigated areas. This approach was adopted in a phased manner and covered all the 30 districts of Karnataka within a span of 4 years, covering 3.73 million ha with major dryland and irrigated crops. With this background, the impact of the Bhoochetana programme using data collected from a large number of farmers' fields during the 4-year period from 2009 to 2012 is discussed in this chapter. These data capture large variability in meteorological, biophysical, socio-economic and agronomic factors in the state.

10.2 Soil Fertility Mapping

The Government of Karnataka along with consortium partners like ICRISAT started the Bhoochetana programme in 2009. To define the soil-test-based fertilizer application at taluk (administrative boundary comprising several villages) and village levels, soil nutrient mapping was considered as the first and foremost entry point activity. A statistically proven stratified soil sampling technique was adopted to collect representative samples from rainfed agricultural land covering the entire state of Karnataka. A large number of samples (92,904) were collected, covering huge spatial variability in terms of rainfall and topography, cropping system, field size and its management. Soil samples were analysed in a state-of-the-art laboratory and a range of soil health parameters (i.e. organic carbon, available phosphorus (P), potassium (K), zinc (Zn), boron (B), sulfur (S), pH and electrical conductivity (EC)) were analysed. Data were used to map the soil nutrient status using a geographical information system (GIS) interface and nutrient-deficient hot spots were identified. Crop-specific nutrient recommendations were prepared and results were shared among consortium partners and stakeholders.

Soil analysis results from the entire state have clearly shown that the majority of the farmers' fields (52%) were low in organic carbon (Wani *et al.*, 2012b). In Karnataka as a whole 41% of farms were deficient in P, indicating the majority of farms had sufficient P and so had the opportunity through site-specific nutrient management to cut costs on current recommendations of P application. K as such was not a problem in the state. Across the state only 23% of sampled fields tested low and a science-led approach calls for a reduction in recommended K. Interestingly, the diagnosis revealed widespread deficiencies of secondary and micronutrients on most farms in Karnataka such that 52% of farms were deficient in S, 55% in Zn and 62% in B. Figure 10.1 shows spatial variability of different soil nutrients for different taluks in the state. It was found that soils are deficient largely in micro and secondary nutrients (S, Zn and B). Deficiency of P was largely found in north-western districts of Karnataka. Test results also showed that organic matter is poor, which largely varied from 0.25% to 0.50%. Western Ghats were found to be relatively good in soil organic carbon content, which could be due to the large area under forest and plantation crops. Moreover, soils in Western Ghats were acidic in nature due to heavy rainfall. Soil pH was found to increase from west to east and from a south to north direction as per the changing rainfall pattern.

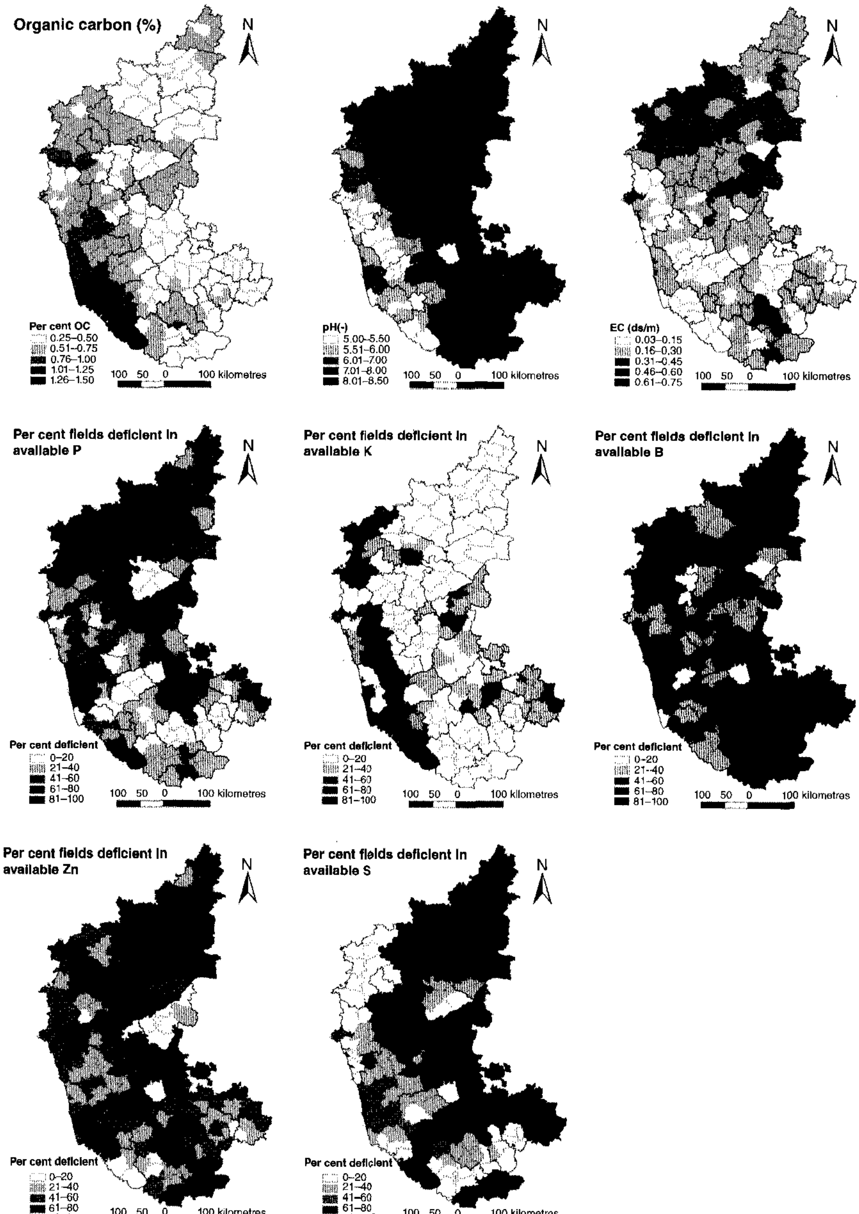

Fig. 10.1. Organic carbon (OC) content, pH and electrical conductivity (EC) of soil and percentage of farmers' fields deficient in available P, K, B, Zn and S in different taluks of Karnataka.

Soil health mapping was the first important output/milestone of the Bhoochetana project which convinced multi-stakeholders to apply crop- and site-specific nutrient application rather than following a common recommendation. Most of the farmers and stakeholders were unaware of widespread deficiencies of secondary and micronutrients and were not including them in their fertilizer management strategies. Considering how essential nutrients are for crop growth, deficiencies were holding back the realization of higher yields. But in a quest to get higher yields, farmers in many parts of the state were adding more than the required amounts of tested macronutrients such as nitrogen (N), P and K although these nutrients were not deficient. Soil health mapping indicated individual nutrient deficiencies scattered differently and thus provided a basis to design new fertilizer recommendations aimed at the level of a cluster of villages (i.e. the block level) to meet varying soil fertility needs as opposed to the current state-level blanket recommendations. Secondary and micronutrients were included in the recommendations, while the amounts of macronutrients were also optimized according to soil test values.

10.3 Spatial and Temporal Variability of Water Resources

ICRISAT developed a one-dimensional water balance model called the 'Water Impact Calculator' (WIC) used for analysing water balance components. The WIC is a generic decision-making tool, which could be applied for any land use and cropping system by providing minimum sets of biophysical and management inputs for partitioning rainfall into different hydrological components. WIC requires the following details as inputs:

- soil (water retention, soil depth);
- weather (evapotranspiration (ET), rainfall);
- crop growth (biomass (kc), root growth function);
- topography (land slope, landform conditions); and
- crop management (date of crop sowing and harvesting, irrigation method).

The model analyses the water balance components on a daily timescale as shown in Eqn 10.1:

$$\text{Rainfall} = \text{Surplus water (Runoff + Groundwater recharge)} + \text{ET} + \text{Change in soil moisture storage} \quad (10.1)$$

The model was run for all the 176 taluks in 30 districts of Karnataka for selected major crops. Water balance components were derived for all 4 years between 2009 and 2012. Agriculture in Karnataka is largely dependent on rainfall and its distribution as 70% of the total agricultural area is under rainfed conditions. The amount of rainfall received during the monsoon period (June–October) in 2009–2012 is presented in Plate 1. Rainfall varied from less than 500 mm in Central and Northern Karnataka to 5000 mm in Western Ghats. Large variability was also found in rainfall distribution in different months (data not shown). There was surplus rainfall in 2009 as most of the taluks received rainfall above normal. In 2010, rainfall was normal but 2011 and 2012 experienced deficit rainfall. The total rainfall received in 2009 was less than 500 mm in seven taluks out of the total 176 taluks of the entire state, whereas 101 and 127 taluks experienced rainfall less than 500 mm during 2011 and 2012, respectively, and thus there was severe drought in the state (Fig. 10.2).

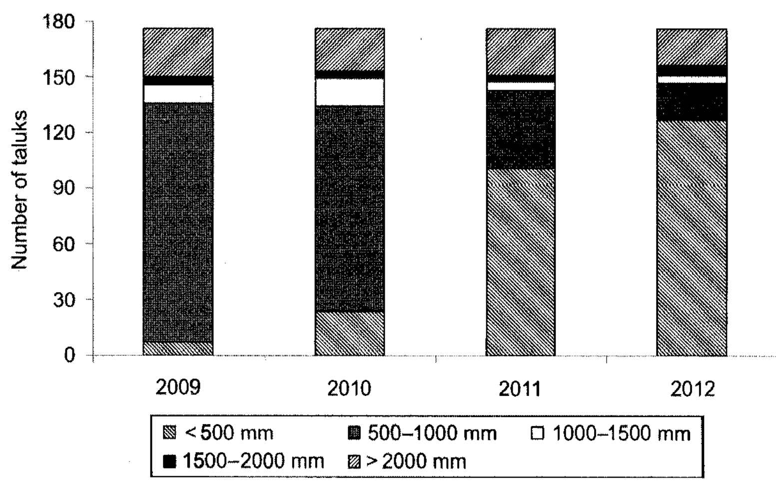

Fig. 10.2. Rainfall variability across Karnataka during 2009–2012.

Water balance components for each of the taluks were derived by hydrological modelling. Total rainfall received during the monsoon period was partitioned into three components: (i) surplus water (surface runoff and groundwater recharge); (ii) ET; and (iii) change in soil moisture content. Surplus water or blue water is the amount of water in which a portion of water flows on the soil surface as surface runoff and joins the riverine ecosystem; and the other portion of blue water contributes to recharge which is available in groundwater aquifers. ET is the amount of water which was initially harvested into soil layers (also known as green water) and subsequently utilized by crops and evaporated from the soil surface. The change in soil moisture indicates the amount of moisture that is left out in soil layers at the end of the monsoon which further could be utilized in the following season.

The water balance showed that a significant portion (nearly 70%) of the total rainfall received in dry regions has been utilized by crops as ET and little is partitioned as blue water. For example, out of 176 taluks in Karnataka state, 101 taluks received an average rainfall of 363 mm during 2011. Out of this, 241 mm (i.e. 66%) of rainfall received partitioned into ET, 32 mm (8%) into blue water and 90 mm (25%) remained as soil moisture at the end of the monsoon (Table 10.1). As rainfall distribution was poor, significant rainfall in October enhanced the soil moisture, which in fact was not useful for a monsoonal crop. Moreover, ET between June and October ranged from 100 mm to 900 mm depending on the rainfall amount and its distribution across the state. Due to poor rainfall in 2011 and 2012, ET in more than 80% of taluks was found to be less than 300 mm during the monsoon period, which shows poor soil moisture availability (Plate 2). This was further translated in terms of poor crop yield. Analysis of crop yield and income with rainfall variability will

Table 10.1. Water resource availability and its distribution in Karnataka during the monsoon (June–October) in 2009–2012.

Rainfall classes (mm)	No. of taluks	Monsoonal rainfall (mm)	Surplus amount (mm)	ET (mm)[a]	Change in soil moisture content (mm)
2009					
< 500	7	442	70	303	69
500–1000	129	691	179	423	89
1000–1500	10	1117	396	626	95
1500–2000	4	1693	812	766	116
> 2000	26	3203	2269	814	120
2010					
< 500	24	452	55	303	94
500–1000	110	644	131	419	94
1000–1500	15	1144	398	644	102
1500–2000	4	1750	830	809	111
> 2000	23	3242	2307	814	121
2011					
< 500	101	363	32	241	90
500–1000	42	634	102	433	98
1000–1500	5	1253	416	735	101
1500–2000	3	1801	882	810	109
> 2000	25	3250	2315	814	121
2012					
< 500	127	292	24	187	81
500–1000	20	643	107	453	83
1000–1500	4	1245	403	752	90
1500–2000	5	1827	921	809	97
> 2000	20	2729	1806	813	110

[a]ET, Evapotranspiration.

be discussed in the next section of this chapter. On the other hand, ET at Western Ghats was found to be at a maximum as paddy (*Oryza sativa*) is the dominating crop under the surplus water conditions; most of the crop water demand was met through rainfall and a significant amount of water was also found to be evaporated from the soil surface.

Taluks having rainfall more than 1500 mm were the main source of blue water for the riverine ecosystem. Out of 176 taluks, three received rainfall of 1500–2000 mm in 2011 and 25 taluks received more than 2000 mm rainfall (Table 10.1); runoff coefficients on average for these taluks were 48% and 71%, respectively.

10.4 Impact of Bhoochetana on Crop Yield

10.4.1 Crop yield with balanced fertilizer application

Along with large-scale implementation of the Bhoochetana programme, farmers' participatory demonstration trials were conducted in selected fields covering the major cropping systems in each taluk. Fields were divided into two parts: (i) improved practice (IP); and (ii) farmers' practice (FP). A balanced fertilizer dose was applied under IP and another part of the plot was cultivated as per the normal FP. Crop yield was estimated by conducting crop cutting experiments. Entire biomasses from a 3 m × 3 m sample area were harvested in both the plots and fresh biomass was measured in the presence of an ICRISAT representative, the Department of Agriculture (DoA) (Karnataka) staff and the farmer. Subsamples were taken and dried in the oven at 65°C and actual yields were calculated. Data were used to monitor the impact of balanced fertilizer application on crop yield and income from 2009 onwards.

The Bhoochetana programme, which initially started addressing soil nutrient deficiency from six districts in the first year, was scaled up to all 30 districts of the state in the third and fourth years, which has made a huge impact on crop productivity. Cropping systems in Karnataka are very diverse and a large number of crops were grown; however, to understand the impact of Bhoochetana, in this chapter we have selected four important crops: (i) maize (*Zea mays*); (ii) finger millet (*Eleusine coracana*); (iii) chickpea (*Cicer arietinum*); and (iv) groundnut (*Arachis hypogaea*). Crop productivity measured by crop cutting experiments under IP was compared with FP over 4 years from 2009 to 2012. The IP enhanced crop yields by 20–66% compared with FP. Crop productivity decreased with decreasing rainfall from 2009 to 2012 but yields under IP were consistently higher compared with FP even during deficit rainfall years in 2011 and 2012.

Average maize yields were 5500 kg/ha and 7600 kg/ha in 2009, and 3900 kg/ha and 5100 kg/ha in 2012 under FP and IP, respectively.

Large variation in crop productivity (maximum to minimum range) is recorded during the dry years compared with wet and normal years. With supplemental irrigation, yield levels obtained by farmers in dry years were even higher than the wet years but under rainfed conditions the crops suffered water stress resulting in poor yield. Finger millet is a drought-tolerant crop and largely grown in the southern part of Karnataka. Average finger millet yields were 1750 kg/ha and 2700 kg/ha in 2009, and 1250 kg/ha and 1680 kg/ha in 2012 under FP and IP, respectively. However, productivity decreased from 2009 to 2012 but IP helped farmers to harness better yields despite high water stress conditions. Chickpea is a post-rainy season crop, which is generally grown with residual soil moisture. It also showed better productivity under IP compared with FP but this difference decreased with increasing soil moisture stress especially in 2012. Average chickpea yields were 1050 kg/ha and 1400 kg/ha in 2009, and 600 kg/ha and 780 kg/ha in 2012 under FP and IP, respectively. Average groundnut yields in the first 3 years (2009–2011) were 1300 kg/ha and 1800 kg/ha but dropped significantly to 600 kg/ha and 780 kg/ha in 2012 under FP and IP, respectively.

10.4.2 Crop yield with rainfall variability

Crop production functions (rainfall versus crop yields) describing the crop sensitivity with available water and its further interaction with nutrient management were derived for:

- major cereals (maize, rice, finger millet, pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*));
- oilseeds (groundnut, soybean (*Glycine max*)); and
- pulses (pigeon pea (*Cajanus cajan*), chickpea, green gram (*Vigna radiata*)).

The Food and Agriculture Organization of the United Nations (FAO) described the linear relationship between crop yield and water use, where relative yield reduction is related to the corresponding relative reduction with available water for crop use (Stewart *et al.*, 1977; Doorenbos and Kassam, 1979; Lovelli *et al.*, 2007) as shown in Eqn 10.2.

$$\left[\frac{Y_x - Y_a}{Y_x}\right] = K_y\left[\frac{\text{Available water}}{\text{Actual water need}}\right] \quad (10.2)$$

where Y_x is maximum yield and Y_a is actual yield, and K_y is the correlation or proportionality factor between the related productivity loss (Lovelli *et al.*, 2007). In the current study, the production function for selected crops is established from large-scale farmers' field data from 2009 to 2012.

To understand yield sensitivity with monsoonal rainfall, the average yield measured in different taluks was plotted against rainfall for important cereals (paddy, maize, pearl millet, finger millet, sorghum), pulses (chickpea, green gram, pigeon pea) and oilseeds (soybean, groundnut) both under FP and IP (Figs 10.3 and 10.4). In general, crop yield increased with increasing rainfall amount but huge variability was recorded even in the same rainfall class. This variability was due to variation in rainfall distribution, soil types (nutrient status, moisture holding capacity, etc.) and a number of management factors (fertilizer input, time of sowing, etc.) among taluks.

Paddy is largely grown under irrigated conditions in drylands. It is also grown under rainfed conditions where rainfall is high. As we have not acquired total water inputs (rainfall plus irrigation) for paddy, it is at least important to analyse crop yield with rainfall. Most importantly, paddy yield under IP is higher (Student *t*-test, $P < 0.001$, nearly an additional 600–1000 kg as shown by the trend line) than FP, which indicates the importance of micro and secondary nutrients even under the higher yielding scenarios. Data plotted from a large number of crop cutting samples showed that maize yield in general increased with increasing rainfall. Farmers apply supplemental irrigation as maize is a water-demanding crop. Achieving relatively moderate to higher grain yield in poor rainfall scenarios (200–300 mm) indicates application of supplemental irrigation. The maize yield irrespective of irrigation inputs with IP was 800–1500 kg higher ($P < 0.001$) compared with FP (Fig. 10.3). Farmers generally cultivate pearl millet, finger millet and sorghum in low rainfall regions (less than 800 mm). Yields of these crops also increased with better water availability and a 500–800 kg difference in crop yield was found between FP and IP ($P < 0.001$). Similar observations were recorded for pulses and oilseeds (Fig. 10.4).

Further, yields for every 100 mm rainfall range were grouped together and averaged; productivity functions for selected cereals, pulses and oilseeds were developed (Figs 10.5 and 10.6). A linear trend was found in maize productivity with increasing rainfall, whereas productivity of pearl millet and finger millet increased linearly up to 600–700 mm but started declining with increasing rainfall, indicating that these crops are resilient in dry climatic conditions. The production function developed for pulses (chickpea, green gram and pigeon pea) and oilseeds also showed a strong linear response with increasing rainfall (Fig. 10.6).

To compare the economic benefit from different crops, we translated crop yields into net income after subtracting the cost of cultivation from gross income both for FP and IP scenarios and also compared it with rainfall variability (Figs 10.7 and 10.8). Paddy and maize were more remunerative crops compared with millets and sorghum. Net income from maize and pearl millet cultivation was ₹50,000–60,000/ha and ₹20,000–25,000/ha, respectively, under moderate to good rainfall

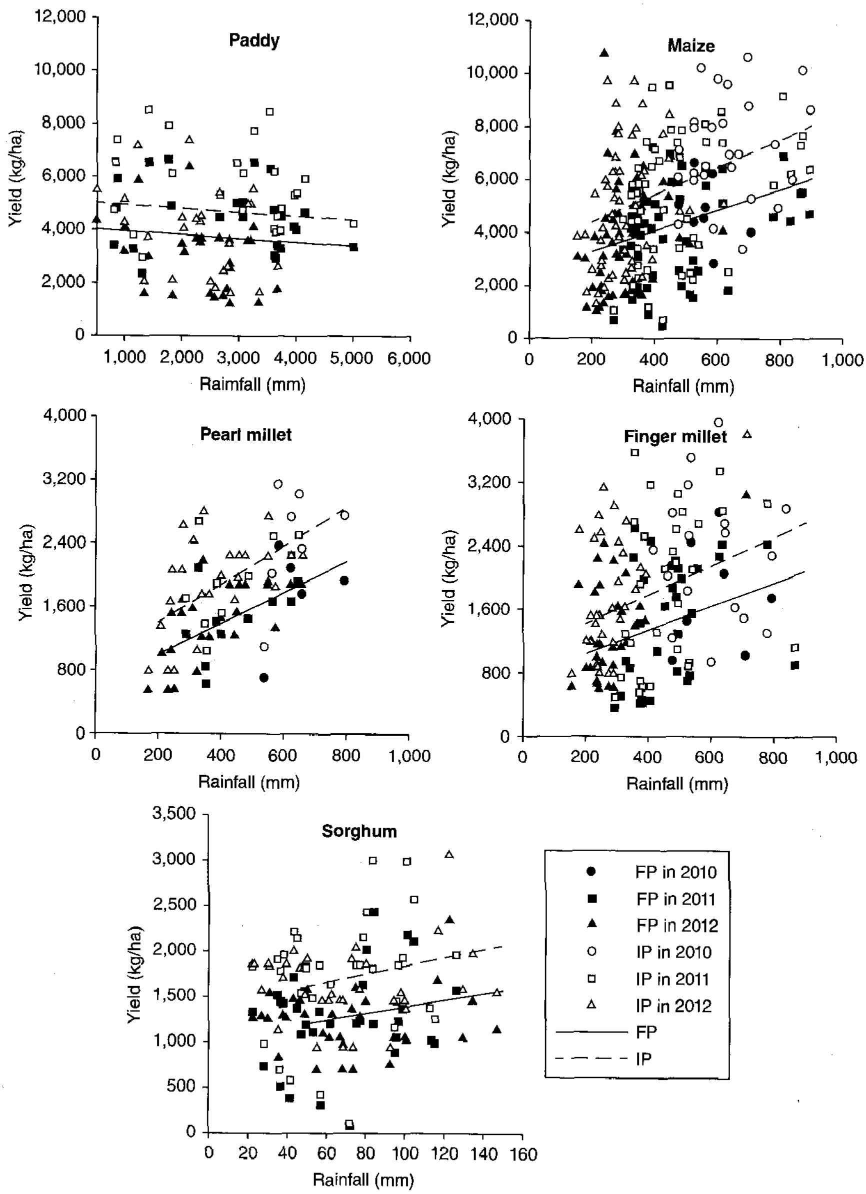

Fig. 10.3. Yield of selected cereals with rainfall and balanced fertilizer application in Karnataka during 2010–2012. Filled and open symbols represent crop yield under farmers' practice (FP) and improved practice (IP), respectively; solid and broken lines further show the yield trend with increasing rainfall amount under FP and IP, respectively.

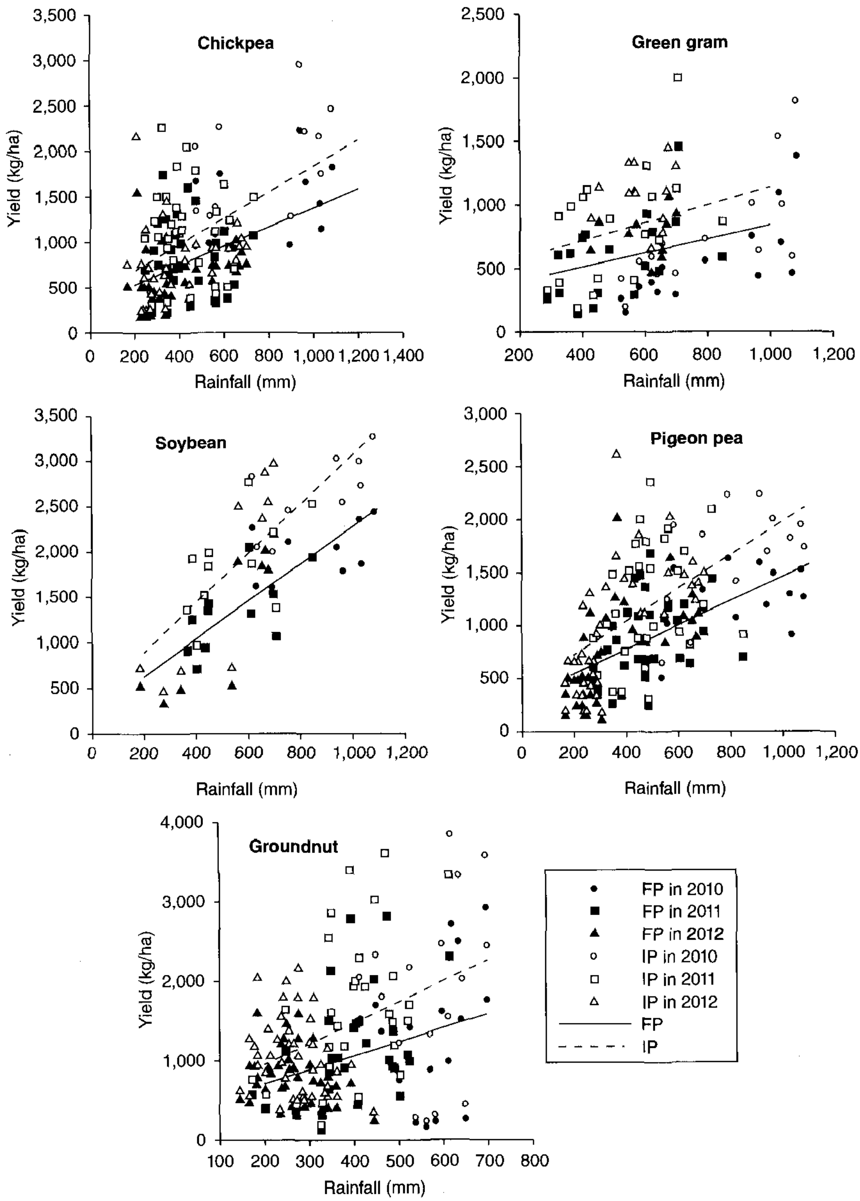

Fig. 10.4. Yield of selected pulses and oilseeds with rainfall and balanced fertilizer application in Karnataka during 2010–2012. Filled and open symbols represent crop yield under farmers' practice (FP) and improved practice (IP), respectively; solid and broken lines further show the yield trend with increasing rainfall amount under FP and IP, respectively.

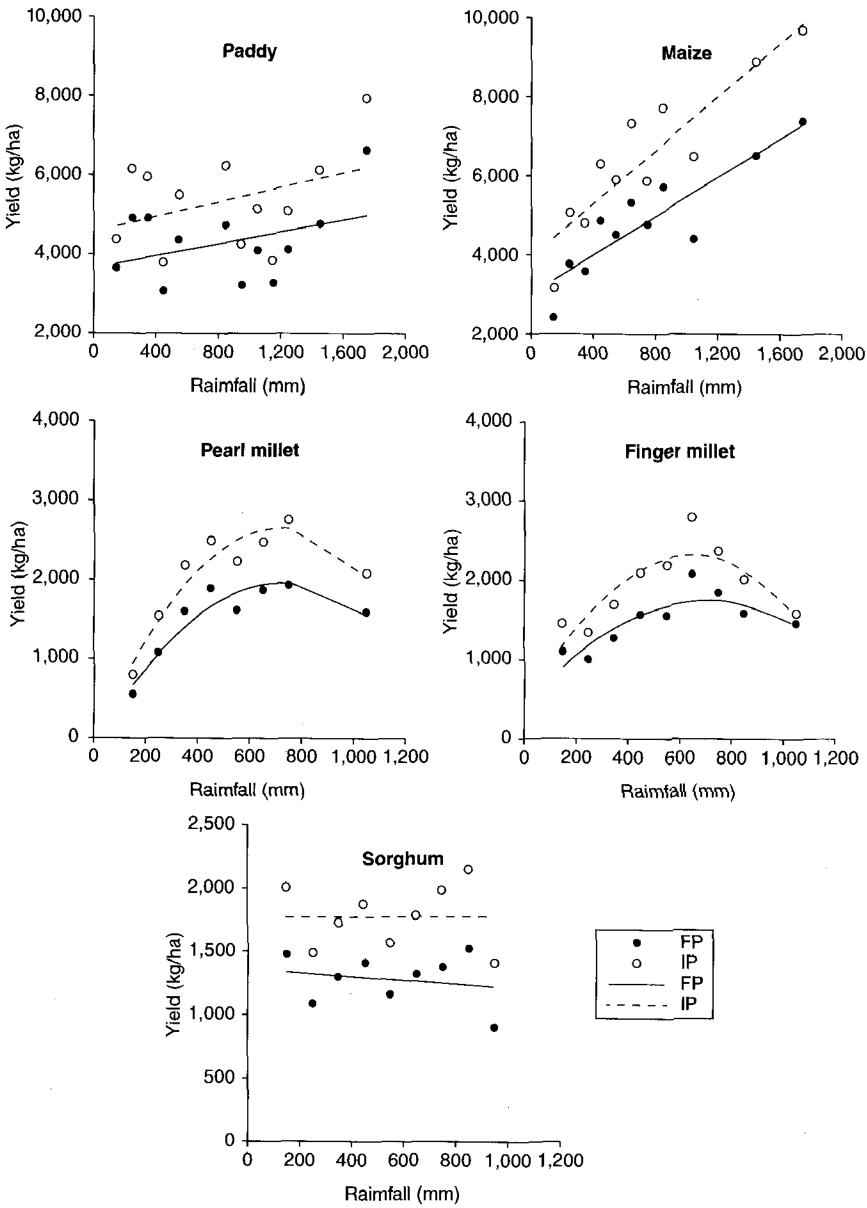

Fig. 10.5. Crop production function of major selected cereals obtained by averaging-up large-scale crop cutting experiments data under different rainfall classes with every 100 mm increment. Filled and open circles represent crop yield under farmers' practice (FP) and improved practice (IP), respectively; solid and broken lines further show the crop yield trend with increasing rainfall amount under FP and IP, respectively.

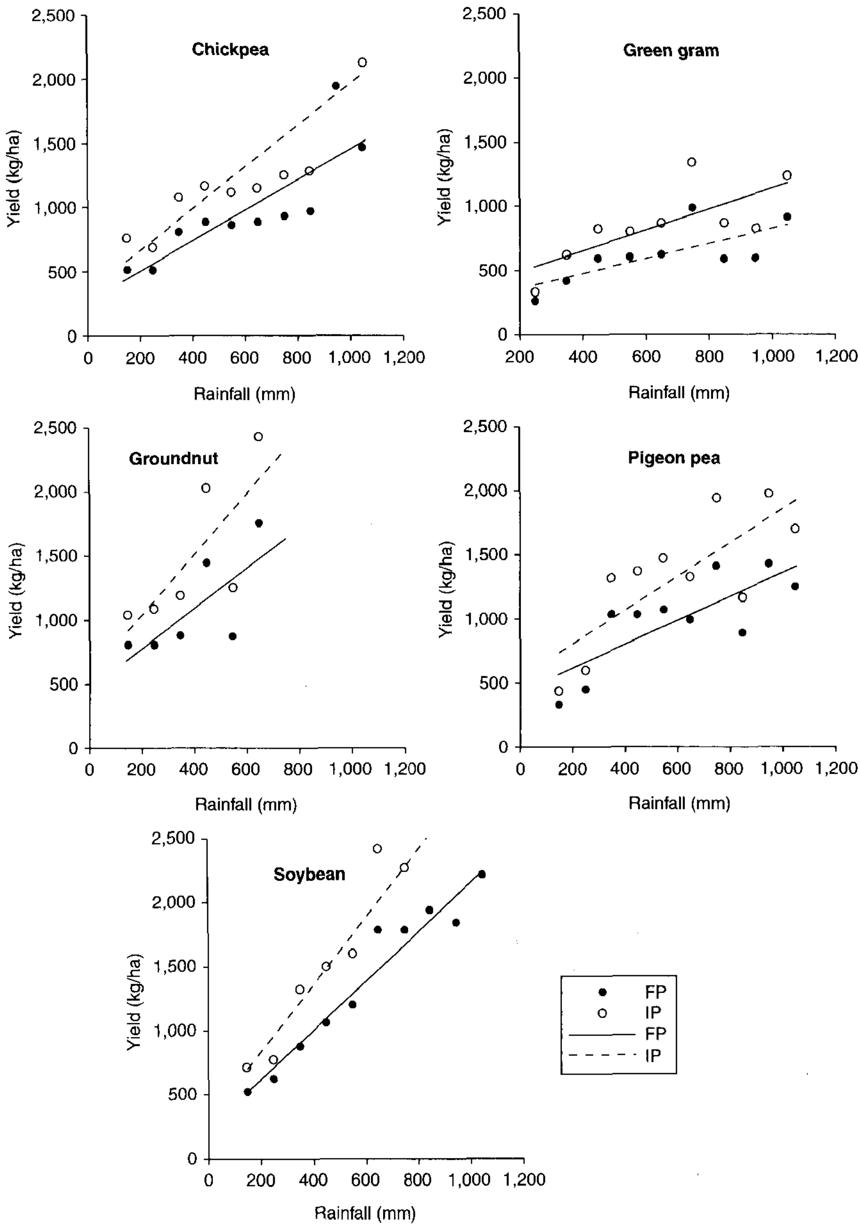

Fig. 10.6. Crop production function of major selected pulses and oilseeds obtained by averaging-up large-scale crop cutting data under different rainfall classes with every 100 mm increment. Filled and open circles represent crop yield under farmers' practice (FP) and improved practice (IP), respectively; solid and broken lines further show the yield trend with increasing rainfall amount under FP and IP, respectively.

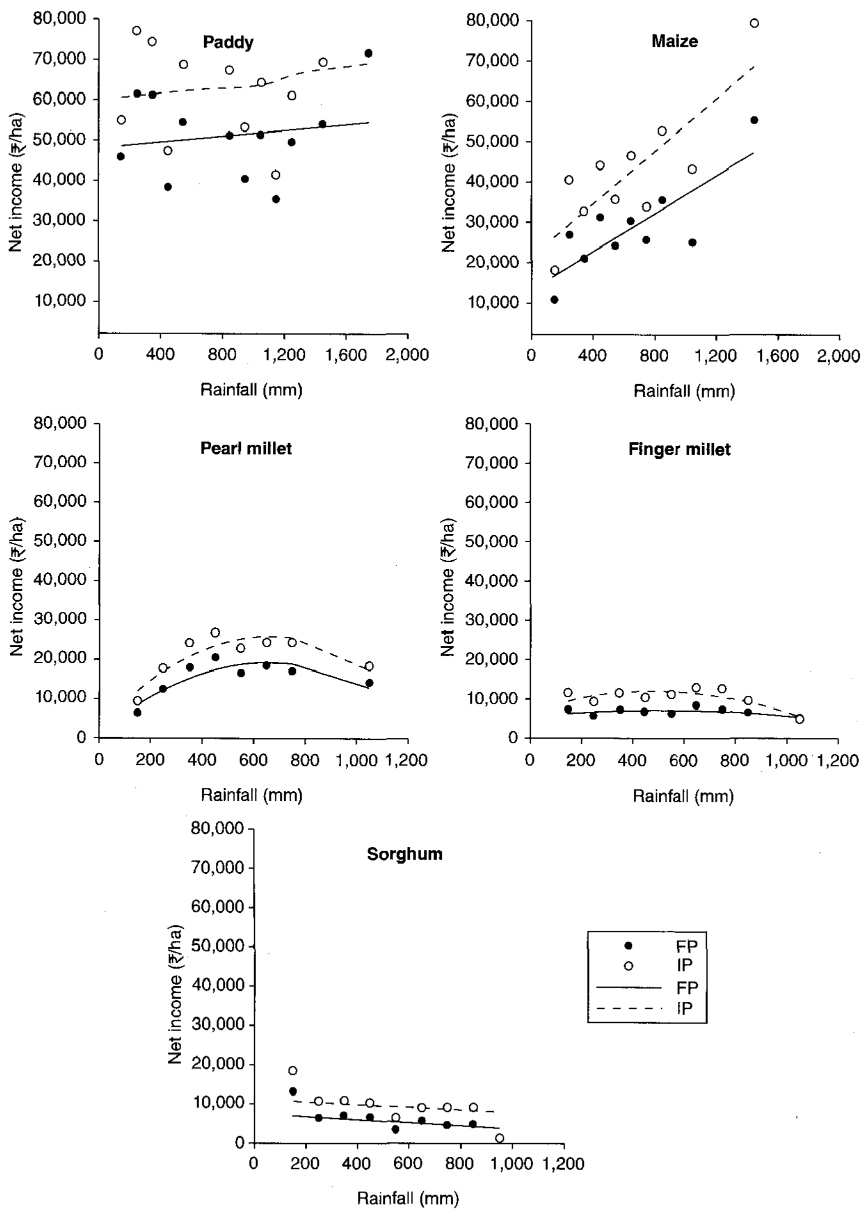

Fig. 10.7. Economic gain (net income) and its sensitivity with increasing rainfall for selected cereals. Filled and open circles represent estimated net income under farmers' practice (FP) and improved practice (IP), respectively; solid and broken lines further show the net income trend with increasing rainfall amount under FP and IP, respectively.

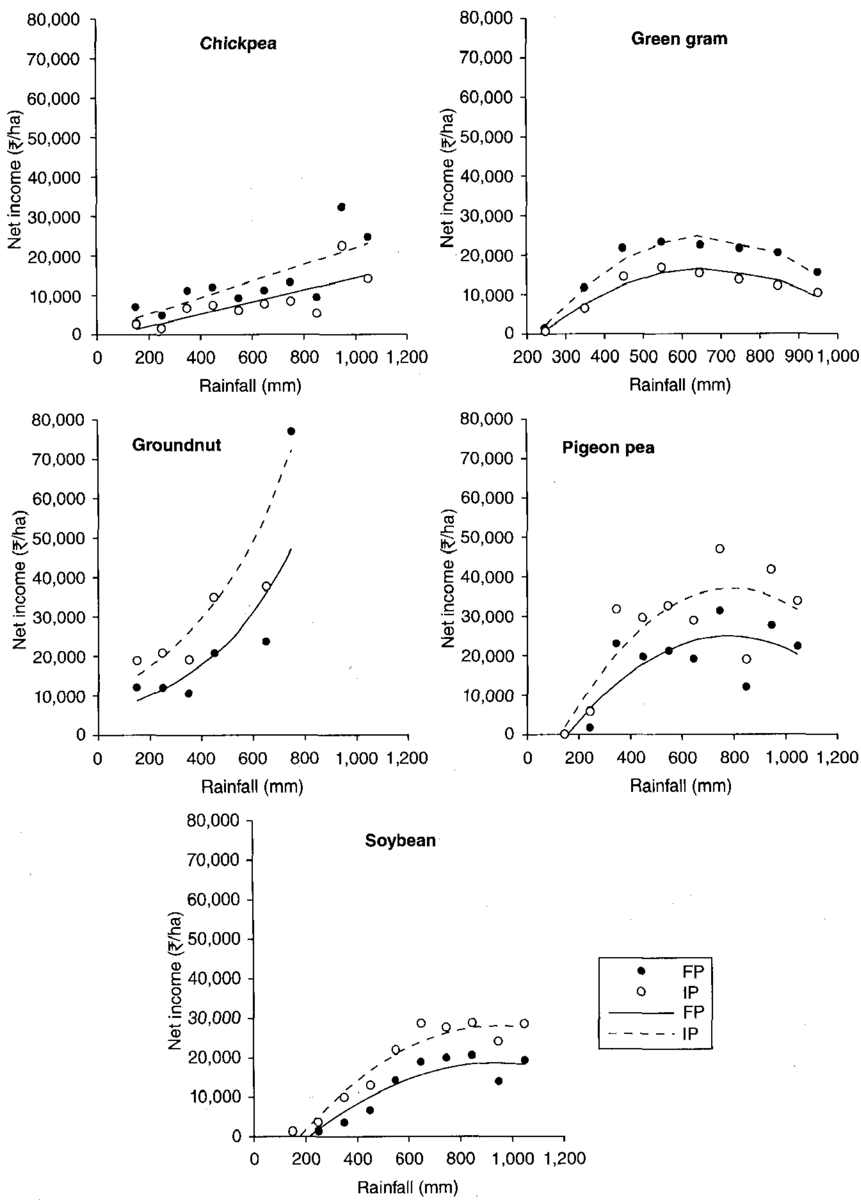

Fig. 10.8. Economic gain (net income) and its sensitivity with increasing rainfall for selected pulses and oilseeds. Filled and open circles represent the estimated net income under farmers' practice (FP) and improved practice (IP), respectively; solid and broken lines further show the net income trend with increasing rainfall amount under FP and IP, respectively.

conditions (600–800 mm) under IP. IP enhanced the net income by ₹8000–10,000/ha under maize and nearly ₹3000–5000/ha under millet and sorghum production. Among pulses, pigeon pea was more remunerative as net income obtained from this crop varied from ₹20,000 to 25,000/ha at moderate rainfall of 800 mm. IP enhanced the net income further to ₹8000–10,000/ha. On the other hand, groundnut was very sensitive with application of micro and secondary nutrients. Net income for groundnut cultivation increased by ₹5000–15,000/ha with IP as compared with FP.

10.4.3 Spatial distribution of crop yields

Spatial variability in cereal productivity among different taluks was analysed. Yield and income obtained from cereal crops under FP and IP in 2012 are shown in Plate 3. Several crop layers overlaid each other; therefore, some of the plotted data are hidden, as they are covered by other layers, however, a comprehensive overview of the cropping system is depicted. Paddy is found largely in the high rainfall zone such as the western part of Karnataka and hilly regions (Western Ghats) where annual rainfall is higher than 1500–2000 mm. Maize is cultivated in the central part of Karnataka covering the state from north to south. Pearl millet and sorghum are cultivated in northern Karnataka and finger millet in southern Karnataka. Results showed that IP enhanced crop productivity in most of the taluks compared with FP. Thus, farmers benefited with additional income of about ₹2500/ha (minimum) to ₹30,000–350,000/ha (maximum). Net additional income was maximum under maize cultivation followed by paddy and pearl millet. Furthermore, the additional benefit–cost ratio ranged from 2 to 20, indicating impressive returns with IP. Similarly, results are also depicted for pulse and oilseed crops in Plate 4. Yield and income levels increased with IP compared with FP.

10.4.4 Crop yields with improved varieties

The Bhoochetana programme has provided opportunities to harness the potential of rainfed areas and showcased it to several stakeholders for large-scale adoption and helped in enhancing their learning and capacity. Land, water, nutrient and crop management interventions were demonstrated under on-farm conditions. Farmers in various parts of Karnataka are still using indigenous and low-yielding crop varieties. Farmers' participatory field trials were conducted for different crops in different districts of Karnataka. Improved crop varieties were compared with the local variety by growing both varieties side by side under the same management conditions. Data obtained from a number of trials indicated 50–150% higher crop yields with improved varieties compared with the local variety (Fig. 10.9). Plate 5 shows the variability in yield among cereals (finger millet, pearl millet), pulses (chickpea, pigeon pea) and oilseed crop (groundnut) between districts. Results indicate that crop productivity could easily be doubled by introducing new and improved varieties along with application of balanced fertilization application.

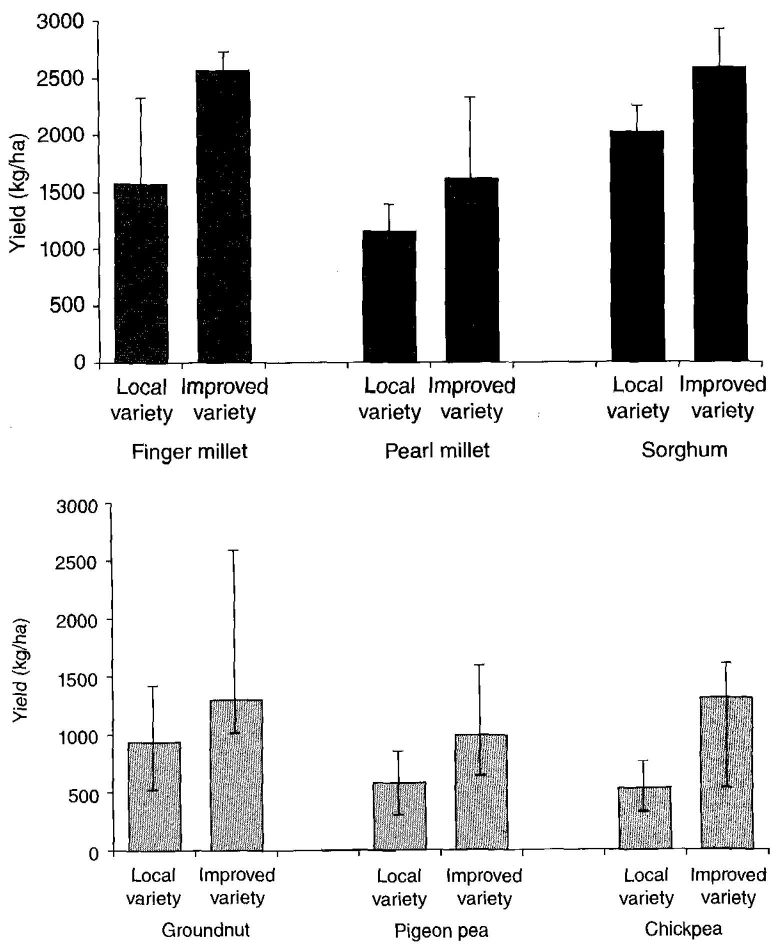

Fig. 10.9. Comparison of crop yield between the local and improved variety of selected cereals (finger millet, pearl millet and sorghum), pulses (pigeon pea and chickpea) and oilseed (groundnut) obtained from farmers' participatory field experiments across the state using data of 2012. Columns show average yields obtained from different crop cutting experiments and error bars show the maximum and minimum range.

10.5 Impact of Bhoochetana on Water Productivity

Crop water productivity (WP) is the amount of grain yield obtained per unit of water used (Tuong and Bouman, 2003; Garg *et al.*, 2012b). Depending on the type of water sources considered, WP is expressed as grain yield per unit water evapotranspired or grain yield per unit of total water input (rainfall under rainfed conditions). In this study, technical WP of IP and FP was calculated using simulated values of ET and yield values obtained for selected cereals, oilseeds and pulses across the entire state. Moreover, economic water productivity (EWP) (₹ per m^3 of water) was also derived using net income obtained against per unit of water use.

Data on average productivity, net income, technical WP and EWP and rainfall are summarized for important cereals, pulses and oilseeds during 2009–2012 in Table 10.2. Average crop yields over the 4-year period were 1810 kg/ha and 2440 kg/ha with FP and IP, respectively. Similarly, the average estimated net income was ₹26,290/ha with FP and ₹35,540/ha with IP, indicating an additional 35% of income by adopting improved management practices. Technical WP with FP and IP was 0.51 kg/m^3 and 0.69 kg/m^3, whereas EWP was ₹5.3/m^3 and ₹7.15/m^3, respectively (Table 10.2).

10.6 Conclusions

Agriculture in India as such, and specifically in Karnataka, assumes much more importance as 60% of people mostly depend on it for their livelihoods. Rainfed agriculture in general is considered as '1 t agriculture' with the perception that not much improvement can be made. Bhoochetana thus became the best example for scaling up in the country and has shown that simple but science-led interventions such as balanced fertilizer application alone can contribute to 30–35% additional yield gain. The total area covered by the programme within the 4-year period between 2009 and 2012 was 3.73 million ha. More than 3 million farmers, including small and marginal farmers from all the 30 districts of Karnataka, benefited from the programme. Field observations and agronomic records also showed that crops were found to be more tolerant to various pests and diseases and yielded better compared with farmers' management practices. The beneficial impact of the Bhoochetana programme is observed in not only wet and normal years but also in dry years. The programme has proven that improved management systems are vital in building the resilience of the farming systems in spite of normal or below normal rainfall in the state. Increase in crop yield and net income by about 30% has contributed to the household budget in rural areas as the benefit–cost ratio ranges from 2 to 20 for different cropping systems and regions.

Table 10.2. Economics of water productivity of selected crops under farmers' practice (FP) and improved practice (IP) for 2009 (wet year), 2010 (normal year), 2011 (dry year) and 2012 (very dry year).

Crop	Data from no. of taluks	Yield (kg/ha)		Net income (₹/ha)		Rainfall (mm)		Technical water productivity (kg/m^3)		Economic water productivity (₹/m^3)	
		FP	IP	FP	IP	FP	IP	FP	IP	FP	IP
2009											
Paddy	–	–	–	–	–	–	–	–	–	–	–
Maize	5	5,472	7,600	45,965	63,840	691	464	1.18	1.64	7	9.3
Finger millet	3	1,737	2,680	15,891	24,522	581	372	0.47	0.72	8	4.3
Pearl millet	–	–	–	–	–	–	–	–	–	–	–
Sorghum	9	1,286	1,878	11,056	16,149	710	443	0.29	0.42	1.6	2.3
Chickpea	6	1,052	1,407	18,194	24,335	654	415	0.25	0.34	2.8	3.8
Green gram	–	–	–	–	–	–	–	–	–	–	–
Pigeon pea	–	–	–	–	–	–	–	–	–	–	–
Soybean	2	1,775	2,630	24,673	36,557	807	529	0.34	0.5	3.1	4.6
Groundnut	8	1,276	1,761	26,801	36,986	594	377	0.34	0.47	4.4	6.1
Average		2,100	2,993	23,763	33,732	673	433	0.48	0.68	3.57	5.07
2010											
Paddy	–	–	–	–	–	–	–	–	–	–	–
Maize	30	5,435	7,275	47,825	64,021	655	421	1.29	1.73	7.7	10.2
Finger millet	22	1,700	2,317	16,405	22,362	624	405	0.42	0.57	2.8	3.8
Pearl millet	8	1,709	2,394	15,037	21,065	685	426	0.4	0.56	2.3	3.2
Sorghum	6	1,290	1,832	11,610	16,485	614	390	0.33	0.47	1.9	2.7
Chickpea	13	1,352	1,817	23,787	31,978	759	453	0.3	0.4	3.3	4.4
Green gram	14	546	763	17,299	24,183	800	473	0.12	0.16	2.1	2.9
Pigeon pea	14	1,212	1,631	36,364	48,943	836	489	0.25	0.33	4.5	6
Soybean	9	2,008	2,650	28,812	38,022	863	500	0.4	0.53	3.4	4.5
Groundnut	18	1,297	1,814	29,831	41,732	572	371	0.35	0.49	5.2	7.3
Average		1,839	2,499	25,219	34,310	712	436	0.43	0.58	3.69	5

Continued

Table 10.2. Continued.

Crop	Data from no. of taluks	Yield (kg/ha)		Net income (₹/ha)		Rainfall (mm)		Technical water productivity (kg/m³)		Economic water productivity (₹/m³)	
		FP	IP	FP	IP	FP	IP	FP	IP	FP	IP
2011											
Paddy	25	4,477	5,583	48,354	60,294	2,720	776	0.58	0.72	2.4	3.1
Maize	48	3,998	5,348	39,178	52,414	470	320	1.25	1.67	9	12
Finger millet	39	1,552	2,037	16,297	21,393	485	317	0.49	0.64	3.4	4.4
Pearl millet	12	1,714	2,373	16,799	23,259	415	293	0.58	0.81	4.2	5.8
Sorghum	32	1,369	1,833	13,691	18,328	451	304	0.45	0.6	3.2	4.4
Chickpea	31	855	1,151	17,945	24,164	407	278	0.31	0.41	4.8	6.5
Green gram	18	585	826	20,475	28,894	484	329	0.18	0.25	4.3	6.1
Pigeon pea	28	922	1271	29,509	40,663	473	323	0.29	0.39	6.2	8.4
Soybean	11	1,316	1,850	22,247	31,265	520	358	0.37	0.52	4.4	6.3
Groundnut	31	1,381	1,963	37,295	52,998	389	261	0.53	0.75	9.1	13
Average		1,817	2,424	26,179	35,367	681	356	0.5	0.68	5.1	7
2012											
Paddy	48	3,694	4,683	46,180	58,539	1,375	512	0.72	0.91	10.6	13.3
Maize	54	3,939	5,204	46,286	61,148	318	213	1.85	2.44	15.4	20.4
Finger millet	45	1,256	1,676	18,847	25,147	283	173	0.73	0.97	6.8	9
Pearl millet	25	1,546	2,056	18,170	24,153	380	259	0.6	0.79	4.8	6.5
Sorghum	31	1,267	1,686	19,265	25,634	388	259	0.49	0.65	5.5	7.3
Chickpea	30	611	794	17,117	22,223	382	255	0.24	0.31	5	6.5
Green gram	12	819	1,086	36,043	47,777	592	404	0.2	0.27	6.2	8.2
Pigeon pea	41	826	1,066	31,805	41,054	367	243	0.34	0.44	8.8	11.4
Soybean	12	1,167	1,568	25,667	34,485	465	305	0.38	0.51	5.3	7.1
Groundnut	45	792	1,052	29,320	38,932	274	175	0.45	0.6	11.4	15.1
Average		1,815	2,460	26,190	35,457	636	371	0.5	0.68	5.2	7.03

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