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The viability of cotton-based organic farming systems in India

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Cotton farmers in many developing countries are facing decreasing marginal returns due to stagnating yields and high input costs. Conversion to organic management could offer an alternative. In a two year comparative study in central India covering 170 cotton fields, organic farms achieved cotton yields that were on par with those in conventional farms, whereby nutrient inputs and input costs per crop unit were reduced by half. Due to 10–20% lower total production costs and a 20% organic price premium, average gross margins from organic cotton fields were 30–40% higher than in the conventional system. Although the crops grown in rotation with cotton were sold without premium, organic farms achieved 10–20% higher incomes from agriculture. In addition to these economic benefits, the organic farming system does not burden soil and groundwater with synthetic fertilizers and pesticides. However, in this study only minor differences were detected in soil fertility parameters of organic and conventional fields. Altogether, the results suggest that conversion to organic farming can improve livelihoods of smallholders while protecting natural resources. Income loss due to reduced yields in initial years of transition, however, constitutes a major hurdle, especially for poorer farmers. It is thus important to support farmers in overcoming the obstacles of the conversion period.

Keywords: organic agriculture, relative competitiveness, soil fertility, sustainable livelihoods

Introduction

Discussions on whether conversion to organic agriculture is a suitable option for farmers in developing countries have been controversial in the recent past (Goklany, 2002; Pretty *et al.*, 2003; Tilman, 1998; Trewavas, 2001). Extrapolating from experience in industrialized countries, some critics argue that organic farming systems cannot produce sufficient yields to ensure food security and to provide enough income for smallholder farmers in developing countries. While the economic and ecological impact of organic farming systems has been studied extensively in temperate zones (Drinkwater *et al.*, 1998; Lotter, 2003; Mäder *et al.*, 2002; Offermann & Nieberg, 2001; Reganold *et al.*, 1993; Stolze *et al.*, 2000; Tilman *et al.*, 2002), little research has been done on the performance of organic farming in tropical regions. Recent case studies highlight the potential of organic farming for poverty reduction and more sustainable livelihoods in developing countries (Giovannucci, 2005; Parrott & Marsden, 2002), but up to now these claims have lacked scientific evidence. Getting a clearer understanding of the productivity and profitability of tropical organic farming systems could thus have important implications for agricultural and development policies.

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To investigate this issue, we use the example of organic farms in central India that cultivate cotton as their main cash crop. Cotton production in India provides livelihood for about 10 million households (Baffes, 2004). India ranks third among the cotton producing countries, producing about 16% of the world cotton fibre production in 2005, but due to low productivity it has the largest area under cotton cultivation (*ca.* 9 million ha) (ICAC, 2005). The promotion of hybrid varieties, synthetic fertilizers, pesticides and irrigation helped to increase cotton yields in India by a factor of two between 1960 and 2000 (FAOSTAT, 2006). In 1993, 40% of the pesticide volumes used in Indian agriculture were applied on cotton, though this crop covered only 4% of the cultivable land (Venugopal, 2004). The intensive farming practices in cotton have shown a range of problematic side-effects on natural resources and farm households (for a recent overview, see Kooistra & Termorshuizen, 2006). Insect pests that developed resistance, and loss of ecological balance among pest and predator populations have led many cotton farmers into a 'pesticide treadmill' of increasing pesticide application and thus pest management costs (Myers & Stolton, 1998; Poswal & Williamson, 1998). Indian cotton farmers report that the intensive use of synthetic fertilizers eventually reduced the fertility of their soils and that yields are stagnating (Menon, 2004). The resulting high input costs and decreasing marginal returns have led many Indian cotton farmers into indebtedness (Lanting *et al.*, 2005; Rao, 2004).

As an attempt to improve the ecological and socioeconomic sustainability of cotton production, organic cotton initiatives were started not only in India, but also in other Asian, African and south American countries. This development has benefitted from increasing market demand for organic cotton fibre, with several large textile brands and retailers expanding their sales of organic garments (Ton, 2004). The production of certified organic cotton fibre is estimated at 31,000 tons for 2006, with retails of organic cotton products reaching a turnover of 583 million US$ (Klein, 2006).

In this paper we compare the performance of certified organic cotton farms that have been managed organically for 3–10 years with the prevailing (conventional) system. Specifically, we investigate the impact of organic management on cropping patterns, material inputs and outputs, the economic performance and – to a limited extent – on soil fertility parameters. To our knowledge this is presently the most comprehensive and in-depth field study of organic farming in a developing country.

Study area and research methods

The case study

Out of the 10 larger organic cotton initiatives that are presently operational in India, we selected the case of Maikaal bioRe® India Ltd. in Madhya Pradesh for this study, as its size allows for representative sampling and the organic system is in place for a sufficiently long period to assess long-term impacts. Maikaal bioRe has produced organic cotton since 1991, and now involves more than 1500 small-and medium-sized farms (Remei AG, 2005). They are located in the Nimar Valley in central India (200–300 m above sea level), that spreads along the Narmada River. Major soils in the case study region are vertisols, entisols and inceptisols. The climate is semi-arid, with an average annual precipitation of 800 mm in a single peak monsoon season. Farming is partly rain fed, partly irrigated through wells and pipelines from the Narmada River. Cotton is grown in rotation with cereals, pulses and other food crops (the rotation period is usually 2–3 years), and most farmers keep some cattle for dairy, dung production and for use as draft animals.

Maikaal bioRe provides the associated farmers with training and technical advice on organic cotton production and purchases the cotton with a 20% price premium on actual market rates. In other organic cotton initiatives in developing countries, organic price premiums usually range from 10–30%. The company operates an internal control system and arranges for external organic certification by an internationally accredited agency. Inspections cover all farms and include analysis for pesticide residues and use of *Bt*-cotton varieties (ELISA GMO-test). The company and the associated farms are certified as per the Indian national standards for organic production (APEDA, 2001) and the EU regulation on organic farming (European Union, 1991). Costs for extension, certification and for the organic price premium are recovered by selling the certified organic fibre at a higher price in international markets.

Nutrient management practices in the organic system include intercropping with pulses, the use of farmyard manure and compost of dung, and crop residues that are mostly produced on the farm itself, as well as complementary doses of de-oiled castor (*Ricinus communis*) and rock phosphate (Eyhorn *et al.*, 2005a). Pest management is based on preventive measures such as selecting robust cotton varieties (mostly hybrids of *Gossypium hirsutum*), intercropping of maize and pigeon pea (*Cajanus cajan*) as trap crops, and applying herbal pesticides and repellents prepared on the farm. In case of strong infestation with bollworms (*Heliothis armigera*, *Pectinophora gossypiella* and *Earias* spp.), organic farmers use commercially available preparations of *Bacillus thuringiensis* (*Bt*) and Neem (*Azadirachta indica*). Organic farming practices thus are markedly different from prevailing farming systems, which make regular use of synthetic fertilizers (combined with farmyard manure application), chemical pesticides and, to an increasing extent, genetically modified cotton varieties (*Bt*-cotton). Herbicides are rarely used in cotton production in this region, so that weed management in both systems is mainly based on mechanical weeding. Conventional farmers receive technical advice on management practices from the state-run agricultural extension service and from suppliers of fertilizers, pesticides and seeds.

Data collection and farm sample selection

Data collection covered a period of two complete cropping seasons; 2003 (April 2003 to March 2004) and 2004 (April 2004 to March 2005). While rainfall in the previous year was about 30% below average, 2003 was a year with normal precipitation (in average 866 mm in the studied villages), and farming conditions were comparatively good. In 2004, precipitation was slightly less (769 mm) and the distribution was less favourable, with longer dry periods and some incidences of high rainfall that caused flood erosion and water logging in some fields, thus affecting yields. In previous years, the stringent internal and external control system had excluded 5–15% of the organic farms from the group due to non-compliance with the organic standards–mainly application of small quantities of synthetic fertilizers or pesticides. The rate of defaulting farmers happened to be considerably higher in the two study years; 40% in 2003 and 30% in 2004. Two factors have contributed to this development: first, the occurrence of sufficient rain after a dry year tempted some farmers to boost yields by applying synthetic fertilizer. Second, some farmers were interested to try the *Bt*-cotton varieties strongly promoted by seed companies since 2003. While the high defaulting rates constituted a considerable challenge for the company as well as for the research project, it allowed gaining relevant insight in the motivation of farmers to adopt or drop organic farming.

To compare organic farming with the prevailing practice, we randomly selected 10 out of the 75 villages where Maikaal bioRe was active. In each village, we selected random samples of six certified organic farms that have been associated with the company for 3–10 years, and six conventional farms (randomly selected from complete farmer lists of each village). Distribution of soil types and access to irrigation were about the same in the two groups. Over the entire study period, the research team visited the farms in regular intervals and guided them in keeping detailed records on labour, material and financial inputs and outputs for each of their cotton fields as well as for the main rotation crops. Farms that lost their organic certification during the research period due to the use of chemical fertilizers, pesticides or genetically modified cotton varieties, or that discontinued data collection for other reasons (e.g., lack of time, migration, death), were excluded from the research sample. Due to imbalances of certified organic and conventional farms in two villages, we randomly selected two new villages in the second year of the study. The resulting sample for data comparison consisted of 31 organic farms (58 cotton fields) and 58 conventional farms (112 cotton fields) in 2003, and 38 organic farms (62 cotton fields) and 56 conventional farms (108 cotton fields) in 2004.

Soil sampling and analysis

In both years, we measured the size of all cotton fields through triangulation, using measuring tapes. In order to analyse the influence of soil properties on the agronomic performance, and to assess the impact of organic management on soil fertility, representative soil samples were taken of each field. Samples were taken from the cultivated soil layer (upper 15 cm), using a single gouge auger (Ejkelkamp, 30 mm diameter) and combining 12 samples evenly distributed over the field to one composite sample. The samples were air dried, crushed, and gravel and other particles of more than 2 mm were removed with a sieve. The samples were analysed in the soil laboratory of ICRISAT, Hyderabad, for the parameters listed in Table 1. Nutrient analysis was limited to nutrients that are possibly deficient in the soils of the region.

Data processing and statistical analysis

The comparison of nitrogen inputs of organic manures was based on average nitrogen contents of the applied farmyard manure, compost, vermicompost and de-oiled castor. Irrigation water quantities were estimated based on the irrigation time recorded by the farmer, the engine power of the pump, the depth of the well and the diameter of the suction pipe. For wealth characterization we defined a simple wealth indicator consisting of landholding, equipment value, off-farm income and access to irrigation. With the help of this indicator we divided the farmers participating in the study into three groups of equal size: poor, medium and wealthy. For the calculation of gross margins from rotation crops, the value of the quantities used for home consumption was calculated at prevailing market rates. The significance of differences between mean values of groups was tested with independent samples *t*-test, using the program SPSS 13.0. The regression model for

Table 1 Soil parameters and analytical methods

Soil parameter	*Method*	*Reference*	*Details*
Texture (sand, silt, clay)	Hydrometer method	Day (1965)	Contents of sand (0.05–2.0 mm), silt (0.002–0.05 mm) and clay (<0.002 mm)
Water retention capacity	Pressure membrane method	Klute (1986)	Plant available water, i.e. the difference between field capacity (−33 kPa) and permanent wilting point (−1500 kPa)
Organic carbon content (C_{org})	Tube digestion	Nelson and Sommers (1996)	Using a block digester at 150 °C. This also detects carbon bound to the clay fraction
Extractable phosphorus (P)	Olsen method	Kuo (1996)	Bicarbonate extraction followed by P-estimation by auto analyser
Exchangeable potassium (K)	Ammonium acetate extractable K	Thomas (1982)	Ammonium acetate extraction followed by K-estimation with AAS
Extractable zinc (Zn)	DTPA extraction	Lindsay and Norvell (1978)	DTPA extraction followed by Zn-estimation by AAS
Extractable boron (B)	$CaCl_2$ extraction	Bingham (1982)	0.02 M hot $CaCl_2$ extraction followed by B-estimation by ICP
pH	In water	Thomas (1996)	Dilution of soil with water in the ratio 1 : 2
Total salt content	Electric conductivity	Rhoades (1996)	Dilution of soil with water in the ratio 1 : 2. EC by Pye-Unicam-metre; unit: dS/m

cotton yields was produced with the software program JMP 5.0.1. (ordinary least square; backward elimination of variables with $p > 0.05$).

Results and discussion

Land use patterns

Organic and conventional farms cultivated the same range of major crops in the monsoon season, with cotton being the crop with the highest area share (Fig. 1). The organic farms, however, had lower shares of their land under cotton and cultivated more soybean compared to conventional farms. In both years, 29% of the organic cotton fields had cotton intercropped with legumes, while in conventional fields this share was only 3% in 2003 and 11% in 2004. The more diverse cropping patterns in the organic system therefore reflect the principle of organic farming to maintain diverse crop rotations involving legumes, and to grow intercrops or trap crops. Organic farms also kept 20–30% more cattle per hectare, pointing at the important role that farmyard manure plays in organic farming.

In 2004, 43% of all conventional cotton fields were cultivated with *Bt*-varieties (genetically modified cotton), while the certified organic farmers cultivated a range of different hybrid and non-hybrid varieties. In both systems, some farms uproot a part of the cotton at the end of the monsoon season (June to November) in order to grow wheat in the winter season. The average share of wheat in the organic cotton fields was 19% in 2003 and 21% in 2004, while in conventional cotton fields it was 21% in 2003 and 36% in 2004. This might indicate a trade-off between wheat and cotton in organic farms, compared with conventional, especially in 2004. As organic farmers so far received a price premium only for cotton, they possibly prefer to continue the cotton crop rather than uprooting it for growing wheat.

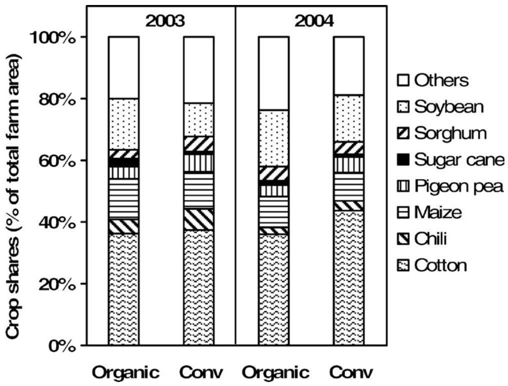

Figure 1 Average shares of major crops in the monsoon season in organic and conventional (Conv) farms in 2003 and 2004

Labour and material input in cotton production

In the first year of the study, organic farms did not use significantly more labour in cotton production than conventional farms (Table 2). In the second year, total labour input (own and hired labour) in organic cotton fields was 13% higher than in conventional fields ($p = 0.06$). Organic farms used 44% and 65% less labour for pest management (in 2003 and 2004, respectively), while labour needed for weeding and for applying fertilizers or manures was about the same. However, these three activities only account for 10–15% of the total work involved in cotton production, while the majority is needed for soil cultivation, irrigation and harvesting.

One of the characteristics of organic farming is that off-farm inputs (fertilizers and pesticides) are substituted by management practices (e.g., intercropping, crop rotation) and inputs produced on the farm (e.g., compost, botanical pesticides). Accordingly, some case studies on organic farming in India report higher labour requirements in the organic system (Giovannucci, 2005). It is thus surprising that in our study labour input was not considerably higher in organic cotton fields. However, so far compost production in the monitored organic farms was not very pronounced: only few farms were following the recommended procedures for setting up and maintaining compost heaps, while the majority was just piling up the available dung and crop residues without turning the heaps or controlling moisture. If composting practices would improve, we estimate that labour requirements increase by 3–5 work days per ha. Even then, labour required for preparing and applying manures would still only account for 3-4% of the total labour input, while the

Table 2 Labour and material inputs in organic and conventional (Conv) cotton fields in 2003 and 2004

Inputs	*2003*			*2004*		
	Organic (n = 58)	*Conv (n = 112)*	*p-value (t-test)*	*Organic (n = 62)*	*Conv (n = 108)*	*p-value (t-test)*
Labour input (days/ha)						
Total labour	206.0	209.4	0.82	173.5	153.1	0.06
Weeding	17.5	16.4	0.59	14.7	13.9	0.53
Fertilizing	3.5	4.2	0.22	2.6	2.8	0.41
Pest management	5.4	9.8	<0.01	1.7	4.8	<0.01
Nutrient input (kg/ha)						
N input	85.3	170.3	<0.01	82.8	136.2	<0.01
from organic manures	85.3	43.7	<0.01	82.8	44.4	<0.01
from synthetic fertilizers	0.0	126.6	<0.01	0.0	91.8	<0.01
P input	25.2	86.9	<0.01	25.4	62.6	<0.01
K input	50.9	54.2	0.70	61.1	59.4	0.88
Water input (m^3/ha)						
Irrigation water	4587	3912	0.25	2944	2804	0.77

n is the number of cotton fields (observations).

majority of the work involved in cotton production still would be required for soil cultivation, irrigation and harvesting. An exploratory study showed that labour input in these activities does not differ between organic and conventional farms (Schumacher, 2004). The time that organic farmers required for attending trainings and for maintaining farm documents for certification was small (approximately 1–2 days/ha) compared to the labour directly involved in production activities.

In both years, average application of organic manure in terms of nitrogen was almost double in the organic cotton fields (Table 2). This shows that organic farmers not only discontinued the use of synthetic fertilizers, but that they took extra efforts to produce or purchase more organic manure and to keep more cattle. Nonetheless, overall levels of nitrogen and phosphorus application of manure or natural mineral fertilizers were lower by a factor of two compared to the quantities applied as farmyard manure and synthetic fertilizers in conventional cotton fields. Potassium inputs were about the same in both systems and years. Lower nutrient input levels are typical for organic farming systems (Parrott & Marsden, 2002), and the results of our study are in line with this general characteristic. Variability in irrigation water application was high, ranging from entirely rain-fed farming to an input of 15,000 m^3 water per hectare. On average, 3.0 to 3.5 m^3 water was used to produce 1 kg of seed cotton. There was no significant difference in water use between farming systems, neither in the applied water quantities nor in the average number of irrigation rounds. However, irrigation water application seems to be mainly determined by access to ground and river water, and availability of electricity to run pumps. To assess whether organic farming can contribute to saving water in cotton production, plot trials would be needed.

Productivity of organic cotton farming

In contrast to the general assumption that yields in organic farming are lower than in conventional farming, there was no significant difference between farming systems in the two years of observation. In 2003, the average seed cotton yield in organic cotton fields was 1459 kg/ha (standard error of mean (SEM): 82.7 kg/ha), whereas in the conventional system it was 1400 kg/ha (SEM: 66.7 kg/ha). In 2004, average yields were 1237 kg/ha (SEM: 104.6 kg/ha) and 1166 kg/ha (SEM: 70.4 kg/ha), respectively. However, yields are also influenced by factors that are not inherently linked to the farming system, like site conditions, the timing of farming operations and irrigation practices. We therefore checked whether uneven distribution of these factors in the samples distorted the results. For this, we estimated a multiple linear regression model for the cotton yields, controlling for all variables that possibly could influence yields but that are not inherent to the farming system (Table 3). Variables that significantly influenced yields ($p < 0.05$) are rainfall, crop duration, plant density, quantity of irrigation water, the year of observation, the wealth status of the farm (based on the wealth indicator described on page 28) and the location (village code). Soil type parameters, the previous rotation crop and the share of wheat in the winter season did not show a significant influence and are therefore not included in Table 3. In this model, average yields were still not significantly different between organic and conventional cotton fields.

Table 3 Estimated yield model controlling for variables that are not inherent to the farming system, and for the farming system effect

	Yield model[a] (n = 334)	
	Parameter estimate	***p-value***
Constant	0.477	<0.01
Rainfall (mm)	0.001	0.02
Log of crop duration (days)	1.033	<0.01
Log of plant density (plants/m^2)	−0.585	<0.01
Log of irrigation applied (L/ha)	0.053	<0.01
Year (for 2003)	0.061	0.01
Wealth status (for poor farmers)	−0.063	0.03
Location (village groups)[b]	−0.225	<0.01
Farming system (for organic farms)	0.022	0.46

n is the number of cotton fields (observations).
[a]The dependent variable is log of seed cotton yield (kg/ha). Adjusted $R^2 = 0.52$.
[b]Four villages were significantly different from the eight other villages.

In view of the much lower nitrogen and phosphorus inputs to the organic cotton fields, it is of particular interest that seed cotton yields were not lower. The regression analysis of cotton yields demonstrates that this cannot be solely explained by the influence of variables that are not inherent to the farming system. The result is supported by the findings of a socioeconomic study conducted in the case study region in 2003 (Shah *et al.*, 2005). Based on recall data stated by 170 interviewed farmers, that study concludes that in 2002 cotton yields on organic farms were on average 2% higher than on conventional farms. Although the small difference and the lack of statistical significance would not justify claiming that organic farming systems achieve higher cotton yields, we can safely assume that yields are not lower for this study. Plot trials on organic and conventional cotton farming conducted by the Central Institute of Cotton Research in Nagpur (http://cicr.nic.in) support this claim: from the seventh year of the trial onwards they found that the organic treatment resulted in 11–21% higher yields compared to the conventional system (Blaise, 2006; Blaise *et al.*, 2004). In a recently initiated organic cotton project in the Indian state of Andhra Pradesh, Lanting *et al.* (2005) found that cotton yields in organic farms were 13% higher than in conventional farms. However, the comparison study was done on a small sample and in a year with exceptionally unfavourable rainfall conditions. Our findings are also in line with observations reported from organic cotton initiatives in Tanzania, Uganda and Benin, where average cotton yields equal those in conventional production (Williamson *et al.*, 2005).

Therefore, we need to ask why the organic farming system can achieve similar cotton yields with much lower nutrient input. One possible explanation is that the more diverse cropping pattern results in additional nutrient inputs from crop residues and nitrogen fixation. Another likely factor is that nutrient losses through leaching are lower and thus nutrient use efficiency is higher for organic manures than for synthetic fertilizers, as Drinkwater *et al.* (1998) observed in maize/soybean agroecosystems. Most farmers whom we asked for their interpretation of the research results attributed the relatively high yield level to improved soil fertility due to organic management practices, particularly the higher input of farmyard manure.

Economic performance of organic cotton

Variable production costs in organic compared to conventional cotton farming tended to be lower by 13% in 2003 ($p = 0.13$) and were lower by 20% in 2004 (Table 4). Variable production costs included hired labour costs, input costs (for seeds, fertilizers and manures, and pest management items), and other costs (for renting equipment, fuel and variable irrigation expenses). In organic cotton farming, costs for hired labour accounted for the largest proportion in variable production costs (53% in 2003 and 48% in 2004), while in conventional farming input costs were the dominating factor (58% in 2003 and 60% in 2004). Input costs in organic cotton fields were 38% lower in 2003 and 44% lower in 2004 than in conventional farms. In both years, input costs per crop unit were lower by a factor two in organic cotton fields. In 2004, the widespread use of *Bt*-cotton varieties increased input costs in the conventional system: while costs for pest management were about the same in *Bt*- and non-*Bt*-cotton production, farmers had spent almost twice as much money on fertilizers and thrice as much for seeds in the GMO crop, compared to conventional non-*Bt*-cotton production.

Considering that organic farms utilized less off-farm inputs but did not require substantially more labour, it is not surprising that total variable production costs in organic cotton farming were lower than in conventional farming. Costs for renting equipment, fuel and irrigation only

Table 4 Economic performance of organic and conventional (Conv) cotton fields in 2003 and 2004 in Indian Rupees (INR) per hectare

Economic performance (INR/ha)[a]	***2003***			***2004***		
	Organic (n = 58)	***Conv (n = 112)***	***p-value (t-test)***	***Organic (n = 62)***	***Conv (n = 108)***	***p-value (t-test)***
Hired labour costs	4,646	3,958	0.09	3,326	2,849	0.22
Total input costs	3,613	5,826	<0.01	2,883	5,143	<0.01
• Seed costs	1,164	1,274	0.31	1,426	2,031	0.03
• Fertilizer costs	1,761	2,858	0.01	1,349	2,147	<0.01
• Pest management items costs	688	1,694	<0.01	107	965	<0.01
Other costs[b]	441	241	0.06	683	651	0.82
Variable production costs	8,700	10,025	0.13	6,892	8,643	0.03
Cotton revenue excl. premium	34,541	31,687	0.27	21,578	20,381	0.58
Cotton price premium	6,908	0		4,316	0	
Cotton crop revenue[c]	41,649	31,726	<0.01	26,048	20,430	<0.01
Revenue from wheat	3,537	4,391	0.55	2,582	5,934	<0.01
Cotton gross margin	32,950	21,701	<0.01	19,157	11,788	<0.01
Wheat gross margin	2,664	3,180	0.63	2,029	4,624	0.01
Field gross margin[d]	35,614	24,882	<0.01	21,185	16,341	0.03

n is the number of cotton fields (observations).
[a]The average exchange rate was 46 INR/US$ in 2003 and 45 INR/US$ in 2004.
[b]Costs for hiring equipment, fuel and variable irrigation expenses.
[c]Including the value of the pulse intercrop.
[d]Sum of the gross margins of the cotton crop and the subsequent wheat crop.

accounted for 5–10% of total variable production costs. Most conventional farmers in the region buy inputs for cotton production on loan, at annual interest rates between 10–15% (from cooperative societies) to over 30% (from private money lenders). As input costs for seeds, fertilizers and pest management items are considerably lower in organic cotton farms, the need to finance inputs and hence service costly loans is far less than in conventional farms. This is particularly relevant in regions where erratic rainfall frequently causes partial or complete crop failure. Indeed, Shah *et al.* (2005) found that organic farmers in the region have lower debt burdens than conventional farmers.

Revenues from the cotton crop include the market value of the cotton harvest (yields multiplied by actual market rates at which the cotton was sold), the intercrop value (on average less than 1% of the revenues from cotton) and in organic farming the 20% price premium for certified cotton. Market rates for cotton fluctuate strongly, and farmers used to sell their cotton in several lots. Average seed cotton rates that organic farmers received when selling to the company (excluding premium) were 5% higher in 2003, while they were 5% lower in 2004, compared to those received by conventional farmers in the open market. Altogether, average seed cotton rates in all farms were 35% higher in 2003 (22.82 INR/kg, the average exchange rate for INR was 46 INR/US$) compared to 2004 (16.85 INR/kg, the exchange rate was 45 INR/US$). Gross margins (revenues including premium minus variable production costs) from organic cotton were higher by 52% (in 2003) and 63% (in 2004), compared to conventional fields (Table 4). If production costs and revenues (cash and in kind) from winter wheat production in the same field are included, gross margins from organic cotton fields still were 43% and 30% higher compared to conventional fields (in 2003 and 2004, respectively). Gross margins for wheat produced in organic cotton fields were lower due to lower area shares cropped with wheat (compare page 29) and slightly lower yields (see page 34), compared to conventional cotton fields.

The results from the two years of observation indicate that, in this context, organic cotton farming can be far more profitable than conventional farming, even if gross margins for wheat that is grown in the cotton field in the winter season and that is sold without organic price premium are included in the calculation. The relative competitiveness of organic cotton farming is particularly noteworthy in 2004, when many conventional cotton farmers cultivated *Bt*-cotton varieties. Even without an organic price premium for cotton, gross margins in the organic system would still have been higher than in the conventional system, by 15% in 2003 and by 3% in 2004. This indicates that organic farming can also be a viable option for farmers who do not have access to organic markets that offer a price premium. However, as we will discuss in the section on ‘Obstacles in organic cotton farming’, part of the organic premium may be needed to compensate farmers for the costs of conversion.

Performance of rotation crops

Although cotton is the main cash crop for most farms in the region, it only accounted for approximately half the profit (cash and in kind value) generated in total crop production. The organic farms also followed the organic standards in the management of the crops grown in rotation with cotton. However, due to Maikaal bioRe’s focus on cotton, the rotation crops were not covered by the extension system, and their products were sold in the conventional market without organic price premium. The full potential of organic farming therefore was not utilized at the time of the study. (Subsequently, training and advice were extended to the main rotation crops, and part of the wheat and soy bean harvest could be sold with an organic price premium.) Keeping these limitations in mind, we compared variable production costs (for inputs, hired labour, fuel and rents), yields and gross margins (revenues based on average market rates minus variable production costs) of the six major crops grown in rotation with cotton – maize, pigeon pea, sorghum, soybean, wheat and chilli (Table 5). In both years, production costs, yields and gross margins were not significantly different between organic and conventional farms. Only in the production of chilli, organic yields and therefore gross margins were considerably lower than conventional. This was

Table 5 Performance of the main crops grown in rotation with cotton in organic and conventional (Conv) farms in 2003 and 2004

Rotation crops	***2003***			***2004***		
	Organic	***Conv***	***p-value***[a]	***Organic***	***Conv***	***p-value***[a]
Maize	($n = 24$)	($n = 39$)		($n = 25$)	($n = 33$)	
Production costs (INR/ha)[b]	1,503	1,702	0.46	1,772	1,824	0.87
Yield (kg/ha)	2,148	2,434	0.44	1,373	1,287	0.73
Gross margins (INR/ha)	8,250	9,122	0.58	5,737	4,837	0.45
Pigeon Pea	($n = 17$)	($n = 38$)		($n = 20$)	($n = 33$)	
Production costs (INR/ha)	1,143	1,770	0.34	940	1,068	0.69
Yield (kg/ha)	533	611	0.48	424	430	0.95
Gross margins (INR/ha)	6,853	7,557	0.64	6,057	6,477	0.92
Sorghum	($n = 9$)	($n = 23$)		($n = 13$)	($n = 14$)	
Production costs (INR/ha)	1,067	1,481	0.70	1,647	1,602	0.92
Yield (kg/ha)	1,540	1,552	0.23	1,022	765	0.51
Gross margins (INR/ha)	4,466	4,676	0.35	3,585	2,224	0.41
Soy bean	($n = 17$)	($n = 29$)		($n = 25$)	($n = 31$)	
Production costs (INR/ha)	1,846	1,865	0.22	3,146	3,395	0.49
Yield (kg/ha)	1,395	1,436	0.98	803	870	0.48
Gross margins (INR/ha)	15,489	16,381	0.89	6,298	7,149	0.53
Wheat	($n = 30$)	($n = 55$)		($n = 36$)	($n = 48$)	
Production costs (INR/ha)	2,051	2,844	0.96	3,281	3,733	0.19
Yield (kg/ha)	2,326	2,486	0.82	2,369	2,472	0.65
Gross margins (INR/ha)	13,302	13,529	0.68	12,115	12,632	0.70
Chilli	($n = 12$)	($n = 30$)		($n = 11$)	($n = 16$)	
Production costs (INR/ha)	6,897	12,664	0.03	6,145	8,174	0.36
Yield (kg/ha)	789	3,146	0.08	424	1,383	0.10
Gross margins (INR/ha)	10,936	25,577	0.06	−354	7,534	0.05
Farm gross margin[c] (INR/ha)	18,134	15,289	0.07	9,606	8,984	0.60

n is the number of farms that cultivated the crop.
[a]Independent samples t-test.
[b]Costs and gross margins are given in Indian Rupees (INR) per hectare.
[c]Average gross margin of cotton and the main rotation crops, excluding investments and management costs.

because for some organic farms the chilli crop failed due to a viral disease – a problem that needs to be addressed by the extension service.

In 2003, the average gross margin from the main crops (including cotton) was 19% higher in organic than in conventional farms (Table 5). In 2004, when area shares under cotton were considerably higher in conventional farms and cotton prices were lower, there was only a tendency that gross margins were 7% higher in organic farms ($p = 0.60$). It is likely that yield levels and thus gross margins of the rotation crops increase if the extension system also provides training and advice on managing these crops organically. The biggest potential to further improve the overall financial performance of organic farms, however, lies in developing organic markets for rotation crops. Products like organic soybean and chilli have some potential in export markets. In India, demand for organic food products like wheat and pulses is also emerging in the domestic market. This market segment is still in its infant stage, but the potential is promising (Rao *et al.*, 2006).

Impact on soil fertility

Heterogeneity of soil properties among the sampled cotton fields was high, ranging from sandy soils on elevations and slopes to heavy clay soils in depressions. The distribution of soil types and average contents of sand, silt and clay did not differ between cotton fields of organic and conventional farms (Table 6). The analysis results have shown only minor and insignificant differences in water retention and in soil organic carbon content. As the organic carbon content in these soils is correlated with the clay content ($R^2 = 0.20$), we also checked the ratio of organic carbon to clay content. Again, there was no significant difference between organic and conventional fields. Contents of soluble phosphorus and potassium as well as total salt contents were not significantly different between farming systems. Boron, a trace element frequently deficient in these soils, was significantly enhanced by 17% in soils of organic cotton fields, while zinc contents did not differ. The higher boron content could be due to increased application of organic manures, as available boron in soils is mainly associated with organic matter (Adams *et al.*, 1991). The pH was slightly, but significantly higher in organic fields (8.24) compared to conventional fields (8.09). The lower pH in conventional fields possibly reflects the acidic reaction of synthetic nitrogen fertilizers.

Most of the organic farmers interviewed during this study stated that after adopting organic management practices they observed remarkable improvements in soil fertility: the soil had become softer, easier to plough, water logging occurred less and the crops sustained periods of drought better (see also Shah *et al.*, 2005). Accordingly, we expected that average soil organic matter contents and water retention capacity in organically managed fields were higher than in conventional fields. One possible reason that our on-farm study did not show these results is that the heterogeneity in site conditions and management practices may have covered differences between farming systems (compare to Mäder *et al.*, 2000). Comparison plot trials under controlled conditions thus seem more appropriate to analyse the impact of organic farming on soil parameters. An analysis of soil samples taken in the eleventh year of a long term plot trial on organic and conventional cotton farming conducted by the Central Institute of Cotton Research in Nagpur showed that soil organic carbon content in the upper soil layer (0–0.2 m) increased by 74% in the organic plots (Blaise, 2006). Water stable aggregates were

Table 6 Soil parameters of organic and conventional (Conv) cotton fields in 2003 and 2004 (combined)

Soil parameters	*Organic (n = 121)*	*Conv (n = 204)*	*p-value (t-test)*
Sand (%)	37.2	38.4	0.45
Silt (%)	22.9	22.4	0.23
Clay (%)	40.0	39.2	0.62
Water retention capacity (g/g soil)	0.13	0.13	0.61
Organic carbon (%)	0.90	0.88	0.48
Organic carbon/clay ratio (*100)	2.43	2.54	0.39
Phosphorus (ppm)	6.48	7.31	0.16
Potassium (ppm)	189	200	0.75
Zinc (ppm)	0.57	0.57	0.96
Boron (ppm)	0.38	0.32	0.01
Salt content (dS/m)	0.30	0.33	0.11
pH	8.24	8.09	<0.01

n is the number of cotton fields sampled.

higher almost by a factor of four, and aggregate size was about double as compared to the conventional system. In addition, the soil nutrient status was significantly better in the organic system, particularly with phosphorus, potassium and some micro-nutrient contents being enhanced (Blaise *et al.*, 2004). Tu *et al.* (2005) found in a system-comparison plot trial in the USA that microbial biomass is more responsive to changes in management practices than soil organic matter. They concluded that the positive accumulative impact of organic amendments and the absence of inhibiting effects of chemical inputs led to increased microbial biomass N and C in the soil.

Obstacles in organic cotton farming

Our comparison study only analysed the performance of farms that have passed the three-year conversion period to organic farming. According to interviews with farmers in the research sample, yields usually declined by 10–50% in the initial 2–3 years of conversion. This initial decline in yields probably has two reasons: first, it takes time until soil fertility and ecological balance respond to the shift to organic nutrient and pest management (Clark *et al.*, 1998); secondly, farmers need to gain experience with organic management practices (Martini *et al.*, 2004). During the conversion period, the reduced production costs and the organic price premium may not be sufficient to compensate for lower revenues, so that farm incomes initially may drop. In addition, some farmers reported that organic farming initially required more work for setting up composting structures and for coping with temporarily increased pest and weed pressure. Although farmers enjoy a better income with the organic system in the long term, managing the obstacles of the conversion period is thus an important entrance barrier, especially for small and resource poor farmers who cannot risk a (temporary) loss of income. It is thus not surprising that in the inception phase mainly larger and wealthier farms have converted (early adopters), whilst poorer farmers have joined in later, as reflected in the decreasing average land holding of the farms associated with Maikaal bioRe over time (from 8.7 ha in 1993 to 3.8 ha in 2004). In order to reduce the initial drop in incomes, we suggest focusing on training and advising farmers on suitable management practices (see Eyhorn *et al.*, 2005b). In addition, organic farming initiatives should be set up in a way that they enable smallholders to participate, and to get support (e.g., inputs, micro-credits) for managing the conversion period (see Eyhorn, 2005).

The fact that 30–40% of the farmers dropped out from the group during the two study years because of using banned inputs shows that not all who once decided to convert to organic farming stick to this system. It is striking that defaulting farmers on average had 60–70% more land and were wealthier, compared to the organic farmers who remained certified. This suggests that defaulting farmers were trying to increase yields by utilizing synthetic fertilizers or genetically modified varieties, while taking the risk that the use of banned inputs is detected and they not only lose the organic premium but are permanently excluded from the group. It is therefore important that project organizers manage to build strong group coherence among participating farmers that together with a stringent and well-functional internal control system can prevent free-riding. (A detailed analysis of the defaulting problem and suggestions for preventive measures are given in Eyhorn, 2007.)

Conclusions

The results of this study suggest that after completing a 2–3 year conversion period, organic cotton farms in India can achieve similar yields as conventional farms, provided they get suitable extension support. As input costs and overall production costs are lower in the organic system, the financial risk for the farmer is lower. Where market demand for organic products offers opportunities to sell part of the produce with a price premium, conversion to organic farming can substantially increase farm incomes, and thus contribute to reducing poverty and indebtedness. At the same time, it allows managing natural resources in a more sustainable way, without the negative side-effects of synthetic fertilizers and pesticides. As yields and incomes usually drop during the initial 2–3 years of conversion, project support needs to be designed in a way that it enables small and marginal farmers to sustain their livelihoods during this phase.

Providing technical advice and facilitating access to credit and off-farm manures are key measures in this (see Eyhorn, 2007).

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