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Economic Performance of Cotton and Fruit Plantations in arid Regions: Observation from the Tarim River Basin, NW China

Haiyan Peng[1], Niels Thevs[1,2*], Volker Beckmann[2] and Nurbay Abdusalih[3]

[1]Institute of Botany and Landscape Ecology, University of Greifswald, Greifswald, Germany.
[2]World Agroforestry Centre, Central Asia Office, Bishkek, Kyrgyzstan.
[3]Institute of Resource and Environmental Sciences, Xinjiang University, Urumqi, China.

Authors' contributions

This work was carried out in collaboration between all authors. Author HP conducted the field work and data analysis. Author NT designed the study and carried out the literature review and corrected the first draft of the manuscript. Author VB supervised the data analysis and corrected the manuscript, too. All authors read and approved the final manuscript.

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ABSTRACT

Arid lands cover 17% of the world's land. There, crop production largely depends on irrigation and frequently faces water shortages. Cotton is grown in arid lands, e.g. Central Asia and Northwest China. Today, the Tarim Basin, Xinjiang, China has turned into the world's most important cotton production region with an annual cotton lint production of 2.1 million t (8.85% of the world production). Against the background of water shortages, cotton farmers in parts of the Tarim Basin have shifted to more highly valuable fruit production, especially *Zyzyphus jujube* (Chinese Date) and the so-called Korla Fragrant Pear (*Pyrus bretschneideri* Rdhd.).

This paper thus aims at assessing the costs, revenues, and profits as well as the return to land and the return to family labor obtained by farmers from those three crops in the Tarim Basin. Data were gathered through farm interviews.

**Corresponding author: E-mail: N.Thevs@cgiar.org;*

Seed cotton yield was 4482 kg/ha in average, with 6155 kg/ha attained by farms under the Xinjiang Production and Construction Corps (XPCC). XPCC, family farms, and commercial farms attained profits of 16846 CNY/ha, 1480 CNY/ha, and 3165 CNY/ha, respectively. Profits from Chinese Date were 53255 CNY/ha and 64279 CNY/ha for family farms and commercial farms, respectively. Among the cotton farm types, the XPCC have the highest profits and return to land. This largely can be explained by the high seed cotton yields of the XPCC farms. Though the XPCC farms are operated by single families, they belong to a strict organization, the XPCC, which urges the families to plant cotton, but provides extension services, too.
Chinese Date has become an attractive alternative for small family farms.
The value of this study lies in the primary data, household interviews, used. This especially applies for commercial farms which are located outside villages and their statistics.

Keywords: Irrigated agriculture; drylands; economic assessment; riparian system; Xinjiang.

1. INTRODUCTION

Arid and hyper-arid lands cover 17% of the world's land and are home for about 10% of the world's population [1]. In such regions the ability to produce agricultural crops is restricted to oases, which obtain water either from surface waters or from the groundwater [2].

Cotton is a crop, which on a global scale is grown in arid and hyper-arid lands, e.g. USA, Central Asia, Australia, Turkey, and the northwest of China. From the 1960s until 1990, i.e. during Soviet Union times, the area under cotton cultivation was hugely enlarged in today's Uzbekistan and Turkmenistan. This strong promotion of cotton was one reason for the desiccation of the Aral Sea [3]. In Xinjiang, northwest China, the cotton production has increased steadily from 1990 until today. Today, the Tarim Basin in Xinjiang has turned into the world's most important cotton production region with a total annual cotton lint production of 2.1 million t, i.e. 8.85% of the world production, in 2010 [4,5]. In 2011, the share of the cotton lint production in Xinjiang of the worldwide production climbed to 11% [5,6]. Half of the cotton in the Tarim Basin is produced along the Aksu and Tarim River [4]. Seed cotton yields in the Tarim Basin range from 4.5 t/ha in the counties, which are dominated by family operated farms, to 6.9 t/ha in the intensively operated military farms [4], while the world average yields is 2.1 t/ha [7]. Similar to the Aral Sea Basin, the expansion of the cotton production in the Tarim Basin resulted in water shortage and ecosystem degradation along the Tarim River [8,9]. Therefore, cotton farmers in parts of the Tarim Basin have been encouraged by the government to shift from cotton to more highly valuable fruit production [10], in order to maintain farmers' income avoiding further increasing water consumption. *Zyzyphus jujube* (Chinese Date) and a local pear variety (*Pyrus bretschneideri* Rdhd.), the so-called Korla Fragrant Pear, stand in the focus of this land use conversion. This paper aims at assessing the costs, revenues and profits obtained by farmers from cotton, Chinese Date, and pear cultivation in the Tarim Basin. Further, in order to compare their competitiveness with regard to the use of land and family labor, two additional indicators are calculated: the return to land and the return to family labor. These indicators allow an assessment of the internal value of land and family labor within the production system. Thereby, this paper also introduces the reality of inputs, costs, revenues, and profits and relative competitiveness with respect to this world wide important cotton production region.

2. STUDY AREA – THE TARIM BASIN

The study area of this paper is the Tarim Basin, located in the southern part of the Xinjiang Uyghur Autonomous Region (hereinafter referred to as Xinjiang) in Northwest China. The Tarim Basin consists of 144 rivers structured into ten river systems. These are the Kaidu-Konqi, Dina, Weigan, Aksu, Kashgar, Yarkant, Hotan, Keriya, Qarqan, and Tarim river system [11]. All rivers, except for the Tarim, originate from the surrounding mountains, the Tianshan, Pamir, and Kunlun. The Aksu River, Hotan River, and Yarkant River flow together at Aral City and form the 1321 km long Tarim River (Fig. 1).

The climate in the Tarim Basin is a typical continental desert climate with scarce precipitation, high evaporation, hot summers and cold winters [12,13]. The annual precipitation ranges from below 50 mm in the center of the Tarim Basin to about 120 mm at its margins, i.e. the foothills of the surrounding mountains, whereas the annual potential evaporation ranges from 2100 to 3000 mm [14].

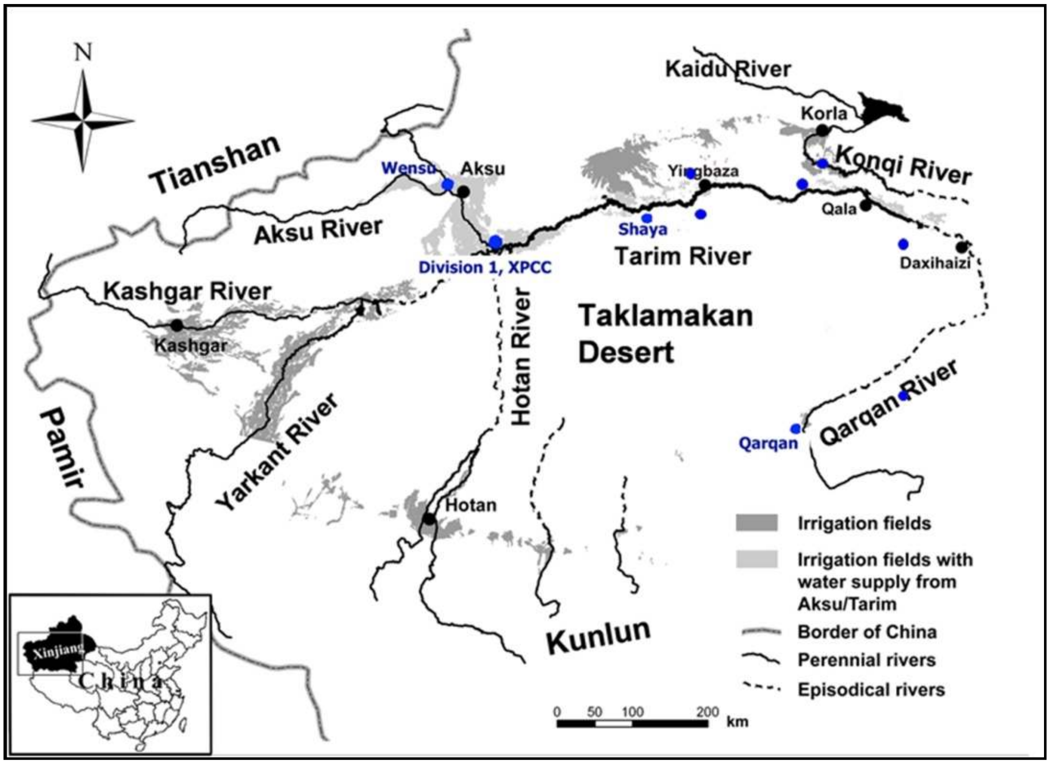

Fig. 1. The Tarim Basin and interview locations

Since the 1950s, the Tarim Basin has seen a rapid population growth together with development of agriculture and industry. The area of irrigated land increased all over the Tarim Basin, from 706,000 ha in 1949 over 1,330,000 ha in 1980 to 1,412,000 ha in 1990 [15], and 1,650,000 ha in 2008 [4]. The entire land cropped with cotton is irrigated due to the arid climate. Nowadays, the Tarim Basin is home to a population of 9.5 million [4]. Through rapid growth of population and agriculture was coupled with increasing demand for water. Due to the increased water consumption all over the Tarim Basin, the downstream sections of most rivers fell dry or suffer periods of water shortage [16]. The Hotan and Yarkant Rivers turned from perennial tributaries of the Tarim River into periodical tributaries by beginning of the 1970s. Today, the Aksu River is the main water source, draining permanently into the Tarim and supplying 73.2% of the total amount of the runoff of the Tarim. The Hotan River and the Yarkant River supply 23.2% and 3.6% in average, respectively, and reach Aral only during flood events [17,18]. In 1972, the Daxihaizi Reservoir (Fig. 1) was constructed. This reservoir cut off the 320 km of the Tarim downstream of Daxihaizi so that this river stretch fell completely dry. The end-lake of the Tarim River, the Lop Nor, comprising an area of 100 km² in the 1950s, disappeared entirely in the early 1970s. The other terminal lake Taitema Lake dried up soon afterwards [17,19]. Due to drainage waters from the irrigation, the salt content of the surface waters and the groundwater has increased so that during the process of land reclamation agricultural land have been given up by farmers and herders due to water shortage and soil salinization [20]. Natural ecosystems have been degraded, especially along the Tarim lower reaches and the rim of the inland delta along the Tarim middle reaches [17]. Today, there is a water allocation plan in place for the Tarim River and its tributaries, which shall guarantee a certain annual runoff through the whole Tarim River into the terminal lake Taitema [8,9,21]. The Taitema Lake has reappeared after 30 years varying in size (maximum area was 200 km²) according to the runoff from the Tarim downstream section. But though this water management program is in place, the Tarim River ceased to flow on more than half of its total river length during spring and early summer 2004, 2007, 2008, and 2009 resulting in crop failures downstream [8,9].

3. FARMING AND LAND USE IN THE TARIM BASIN

Agriculture is the dominant economic sector in the Tarim Basin. The primary sector (farming, forest, animal husbandry, and fishery) has been contributing about half of the regional Gross Domestic Product (GDP) in the Tarim River Basin [22]. Cotton production contributes the largest share of the primary industry part of the GDP. Since 1995, Xinjiang has become the biggest cotton producer in China [6]. About 90% of Xinjiang's cotton production stems from the Tarim Basin. Cotton plantation completely depends on irrigation due to the extremely arid climate in the Tarim River Basin. As water scarcity is a wide spread problem for agriculture in the Tarim River Basin, there are attempts to shift away from cotton. Local authorities mainly promoted fruit trees such as Chinese Date (*Zyzyphus jujube*) and pears (*Pyrus bretschneideri* Rdhd.). The area planted with Chinese Date increased sharply from 2006 until today (Fig. 2).

Chinese Date is a traditional fruit in China and other Asian counties. It is usually served as dry fruits, used in traditional medicine and nourishing food. Date plantations require dry and hot summers but also endure cold winters. Thus, date trees are adapted well to the desert conditions in the Tarim Basin [24]. The fruit yield in the first two or three years is low. Afterwards, the yield increases steadily and comes to the peak when the trees are about 20 years old, then the yield decreases until the trees die. In the Tarim Basin, Chinese Date first was promoted in the oases at the southern rim of the basin, mainly Qarlik (Ruoqiang), Qerqen (Qiemo), and Hotan. Later, counties in Aksu Prefecture tried to promote Chinese Date, too.

Korla Fragrant Pear (*Pyrus bretschneideri* Rdhd.) is a local species in the Tarim River Basin. The fruit is considered juicy, thin skin, crunchy, and very fragrant [25]. Therefore it is called "Fragrant Pear". The plantation area of the "Fragrant Pear" is concentrate in Korla and Yuli County.

Fig. 2 shows the fluctuation of cotton, date, and pear plantation areas from 1990 to 2010 in the Tarim Basin. The peak of cotton plantation appeared in 2007 (1.78 million ha), afterwards, the area decreased quickly to 1.46 million ha in 2010. Pear plantations, due to the limitation of location, has a slight increase through the last two decades, from 0.01 million ha to 0.07 million ha. The governmental statistic data of date is only collected from 2002. The area of date plantation has increased strongly from 0.02 million ha in 2002 to 0.40 million ha in 2010.

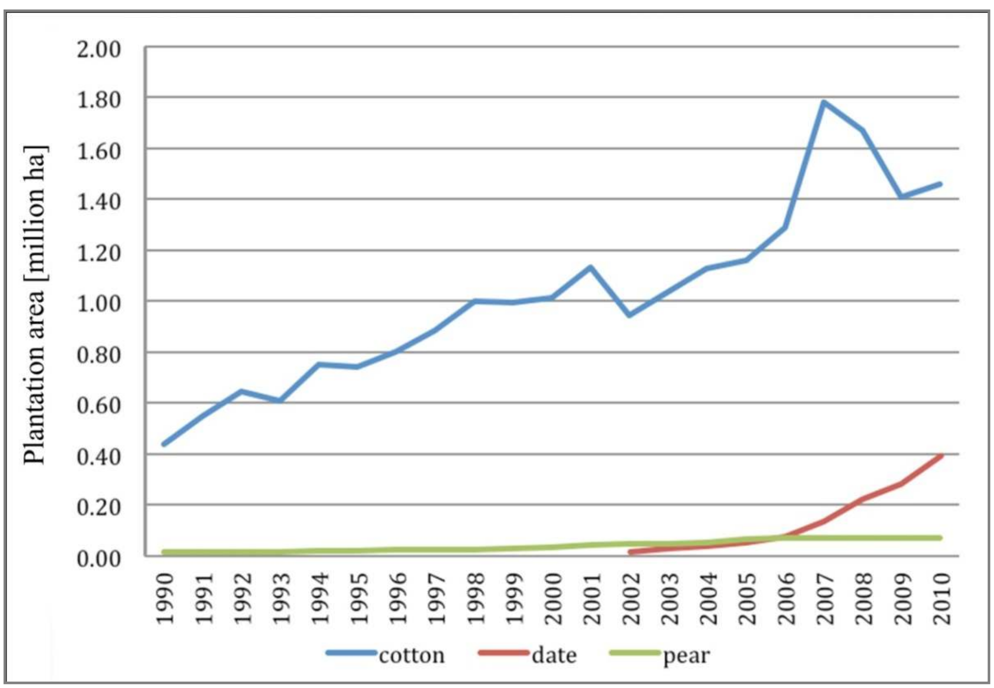

Fig. 2. Plantation area of cotton, date and pear in Xinjiang (million ha) [23]

There are three farm types in the Tarim Basin: (i) small family farms, (ii) large commercial farms, and (iii) XPCC (Xinjiang Production and Construction Corps) farms. In the FAO nomenclature, those three farm types correspond to small semi-subsistence or part-commercial family farms, commercial estates, and commercial family farms [26]. Small family farms dominate in the townships and villages around in the Tarim Basin. Many of them are operated by Uyghur people. Large commercial farms are concentrated along the Tarim River around Yingbaza and in Shaya County. They have been established by private investors and are operated by the investor or a hired farm manager. XPCC farms are under the Xinjiang Production and Construction Corps (XPCC), which was established in the 1950s by the national government as an organization under the army, in order to develop frontier regions, reclaim land for agriculture, and consolidate border defense [27]. The individual XPCC farms underlie a strict organization and intensive management. Cotton as well as Chinese Date are grown by all three farm types, while Pears are planted by small family farms.

4. DATA AND METHODS

4.1 Data collection

The data for this study were gathered through household and expert interviews, which were conducted during several campaigns from 2007 to 2012, in order to track development over time and get a broader foundation of data. Questionnaires with structured and semi-structured parts were used. The following information were asked through structured questions: (i) basic information of the interviewees, (ii) scales of plots, yields and total outputs, (iii) inputs such as seeds, fertilizer, pesticides, labor, machines, lease and other fees, (iv) practices and techniques in cotton, date, and pear planting. Afterwards, through semi-structured questions regarding environmental changes and accessibility to water were asked. Around the Tarim River Basin, interviews were conducted in regions where cotton, date, and pear are cultivated intensively. In total, there are 219 interviews for cotton from 2007 to 2012, 58 interviews for date from 2010 to 2012, and 31 interviews for pear from 2010 to 2012.

4.2 Data Processing and Calculations

All monetary values were adjusted to present values of 2012:

$$V_t = V_{2012}\ CPI_t / CPI_{2012} \quad (1)$$

Where

V_{2012} is the present value inflation adjusted to 2012,
V_t is the value in the year t,
CPI_{2012} refers to CPI of the year 2012, and
CPI_t is the CPI of the year t.

CPI refers to Consumer Price Index of China from OECD (Organization for Economic Co-operation and Development) Stat library [28].

The inputs and profitability of alternative productions were calculated following the standard procedure as outlined in [29]:

	Yield (kg/ha)
*	price (CNY/kg)
revenue (CNY/ha)	
-	variable costs (CNY/ha)
contribution margin (CNY/ha)	
/revenue	
contribution margin ratio (per cent)	
-	opportunity costs of unpaid family labor (CNY/ha)
-	annualized costs of fixed assets (CNY/ha)
-	overhead expenses (CNY/ha)
-	lease of land (CNY/ha)
profit (CNY/ha)	
/revenue	
profit ratio (per cent)	

Variable costs included seeds, fertilizer, herbicides and pesticides, water, energy, maintenance of machinery, and seasonal labor cost. Fixed costs included unpaid labor, annuity of fixed assets, overhead expenses and lease of land. Labor by family members was not paid, thus the method of opportunity cost or market price was applied. In the study of this paper, fixed assets refer to groundwater wells, tractors and water pumps. In contrast to cotton farming, for fruit plantations, trees were planted and grafted only once a life span. Thus, plantation and grafting cost for date and pear plantation were calculated into equivalent annual costs of fixed assets. Overhead expenses referred to interest of loans, land administration fee, taxes, and insurance for the crops.

In order to compare different farm types, the contribution margin ratio and profit rate were calculated. The contribution margin ratio is the ratio between contribution margin and revenue, indicating the importance of variable costs in a certain production mode. The lower the contribution margin ratio is, the more important are variable costs. The profit rate is the ratio between profit and revenue, indicating the profitability of a certain production mode.

In order to evaluate the land uses between cotton, pear and date plantations, the calculation of *return to land* was included. Since land was the entity being compared in land evaluation, costs for lease should not be included in the economic measures [30]. Thus, return to land = profit + lease of land. It determines the economic rent, which indicates the maximum willingness to pay for a certain type of land use.

In order to evaluate the return to unpaid labor by family members, the calculation of *return to family labor* was included. In the calculation of return to family labor, the farmer's family labor was not included as an expense [30]. Thus, the opportunity cost of unpaid family labor was added into the profit. Return to family labor = (profit + opportunity costs of unpaid family labor) / unpaid man-hours. Opportunity costs for family labor were calculated on the basis of the labor costs paid by large commercial farms during the season from planting until harvest and labor costs for cotton harvest.

The equivalent annual costs (EAC) of the fixed assets were calculated according to:

$$EAC = K/a$$
$$a = (1-(1+i)^{-T})/i$$

where

EAC stands for equivalent annual costs of fixed assets, a is the annuity factor,
K refers to purchasing price of fixed assets,
i is the interest rate, and
T is the running time of the asset

The interviews revealed that interest rates for loans which farmers took from banks differed between 8% and 15% depending on regions. Thus, the real interest rates were applied in calculations, instead of a common interest rate.

5. RESULTS

5.1 Cotton Plantations

Cotton is planted in April. Seeds are covered with plastic foil, in order to improve the micro climate, save water, and protect the seedlings against sand storms. Fertilizer is applied with the irrigation. The harvest time is September to November. All harvest is done manually. The harvested seed cotton is sold by the farmers to nearby cotton mills, which extract the seeds and produce lint cotton. One third of seed cotton yield is equivalent to lint cotton yield. In this paper, yields and prices refer to seed cotton.

During a six-year period from 2007 to 2012, the average yield of seed cotton, averaged over all farm types in the Tarim Basin has increased with small fluctuations from 3486 kg/ha in 2007 to 5550 kg/ha in 2012 (Table 1). The maximum yield in this study was reported with 7646 kg/ha from XPCC farms in Aral in 2011. The selling price has also risen from 6.72 CNY/kg in 2007 to 8.22 CNY/kg in 2012. However, in 2008 due to the global financial crisis, the selling price dropped to 5.18 CNY/kg, which resulted in the lowest revenues and profits during this six-year period. Within the years shown in Table 2, the most obvious change occurred from 2010 to 2011, when the yields jumped from 3962 kg/ha to 5550 kg/ha and the selling price also jumped 6.43 CNY/ha to 8.69 CNY/ha. Accordingly, revenues and profits increased despite an increase of the variable costs and producers' costs.

Table 1. Yield, price, input, and profit of cotton plantation from 2007 to 2012 averaged over all three farm types

Year	2007	2008	2009	2010	2011	2012
yield (kg/ha)	3486	4196	4041	3962	5550	5261
price (CNY/kg)	6.72	5.18	6.53	6.43	8.69	8.22
revenue (CNY/ha)	23638	22016	26331	25530	47972	42605
variable cost (CNY/ha)	13175	15882	15074	16337	24276	20500
profit (CNY/ha)	7569	1515	6288	4507	9667	9163

The XPCC farms attained the highest revenue (45279 CNY/ha) and profit (16849 CNY/ha) among the three farm types, because those farms had much higher yields (6155 kg/ha vs. 3684 kg/ha and 4165 kg/ha) and much higher revenues at only slightly higher costs compared to the other two farm types (Table 2). The differences between profits of XPCC farms and the two other farm types investigated is in the same range as the differences between revenues of XPCC and the two other farm types.

The small family farms attain the lowest yields and lowest revenues, while their variable and fixed costs are not much lower than with the XPCC farms and the large commercial farms. Small family farms have the highest unpaid labor costs, because most labor work is contributed by the family members and relatives, whereas, large commercial farms usually employ long-term laborers for planting and field management, and hire seasonal laborers for harvesting. The large commercial farms have high equivalent annual costs of fixed assets because they all have to install water pumps and many have installed groundwater wells. The duration of groundwater wells vary from 2 years to 12 years. They are 60 - 120 m deep, and are abandoned once they run empty or they catch saline groundwater. Water pumps are damaged quickly and need to be renewed every two years due to the sediment load in the river water. The lease paid by large commercial farms is highest among the three farm types, because the land of the commercial farms has been newly reclaimed. For the costs of reclaiming, the farmers had to take a loan from the bank. These costs appear among the lease costs. The overhead expenses of XPCC are higher than others, because XPCC farmers need to pay management fee to their military unit government.

The largest share of the variable costs is seasonal labors and fertilizer costs (Fig. 3). During the harvest season from September to November, about 0.7 million people from mainly Sichuan, Gansu, and Qinghai come to the Tarim Basin to work as seasonal laborers in the cotton harvest mainly on the XPCC farm and the large commercial farms (Tianshan Net 2011). In 2007 the average payment for manual cotton harvesting was 1.06 CNY/kg. However in 2012 it went up to 2 CNY/kg. In XPCC farms and large commercial farms, which have high yields, the cotton harvesting costs occupy about 48% and 40% of the total variable costs. Small family farms hire less foreign seasonal labors, but employ family members as unpaid laborers (Table 2).

All farm types apply equal amounts of fertilizer. Fertilizer costs about 1/4 of the total variable costs. Diammonium phosphate, carbamide, and potassium (mainly KCl) fertilizers are commonly applied. XPCC farms have significantly higher costs for drip irrigation tubes than the other two farm types, which indicates the common implementation of drip irrigation. On the contrary, there is almost no drip irrigation in small family farms. The large commercial farms are usually located along the Tarim River. There, they pump river water for irrigation resulting in comparatively

Table 2. Plot size, yields, cotton prices, revenues, input costs, and profit of cotton plantation in different farm types averaged over the period 2007 to 2012

Farm type	Small family	XPCC	Large commercial
Plot size (ha)	3.08	5.15	97.74
Yield (kg/ha)	3684	6155	4165
Price (CNY/kg)	6.19	7.41	6.82
Revenue (CNY/ha)	22841	45279	28673
Variable costs in sum	15207	19339	17856
Contribution margin (CNY/ha)	7629	25939	10817
opportunity costs of unpaid family labor	4541	2317	678
equivalent annual costs of fixed assets	646	757	2039
Overhead expenses	223	5493	2218
Lease	739	736	2716
Profit (CNY/ha)	1480	16849	3165
Contribution margin ratio	33.4%	57.3%	37.7%
Profit ratio	6.5%	37.2%	11.0%
Return to land (CNY/ha)	2220	17373	5881
Return to family labor (CNY/man-hour)	13.56	39.89	110.27

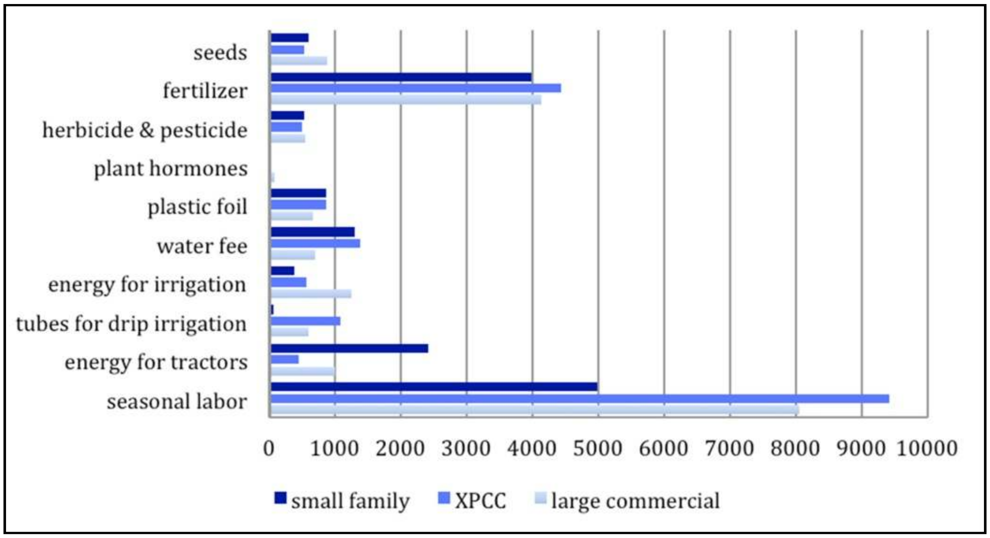

Fig. 3. Variable costs of cotton plantation by farm type averaged over the years 2007 to 2012 [CNY/ha]

high energy costs (cf. Table 2). For small family farms the energy costs for tractors is the third largest share of variable costs after seasonal labor and fertilizer costs.

Though the XPCC farm type has the highest variable costs and fixed costs, it still gains the highest profit, mainly due to its high yields and revenues (Table 2). The profit of XPCC farms is 16849 CNY/ha, which is about 5 times compare to the large commercial farms and 11 times compare to small family farms.

5.2 Chinese Date Cultivation

In the Tarim River Basin, the area of date plantation has been expanded rapidly during the five years (Fig. 2). When establishing a Chinese Date plantation, first wild Chinese Date trees are planted. The following year, the trees are grafted. Due to different varieties and quality of grafts and due to different experiences of farmers in the field of planting and grafting, there are different qualities and final selling prices of date fruit. In the Tarim Basin, farmers´ attitude towards and efforts in date plantation change from one region to another. Farmers in Shaya County carry out date plantation with limited efforts, whereas farmers and local authorities in Qarqan and Qarklick (southern of the basin) manage their date plantations very carefully.

Therefore, during analysis of the interview data, we split the small family farms regarding Chinese Date plantations into so-called active and passive small family farms. In the 1990s, the Central Government launched the program “Return Farmland to Forest” (Tuigeng Huanlin). In brief, farmers on erosion or water shortage prone fields were encouraged through subsidies to give up farming that land, plant trees instead, and do not remove them. Under this program, farmers in Shaya County gave up cotton fields and planted Chinese Date trees there. The trees are not allowed to be removed even though they yield low profits. Farmers do not actively take care for the trees, except for harvesting, so that we call this date farm type passive small family farm. Farmers usually plant corn in summer and wheat in winter below the date trees, so that they may get food for the family and domestic animals. However, as the date trees lay shadow on the crops, the yield of crops is reduced. The date trees receive water and fertilizer as seepage water from the corn and wheat, which hampers their growth and reduces the date yields. In contrast, the farmers in Qarqan and Qarklick manage their date trees very carefully so that we call those farms active small family farms. The local governments in Qarqan and Qarklik provide support to the farmers, by organizing seminars, providing technicians for field management, and making advertisement for the local brands of dates. As a result, the revenues and profits are much higher than of the passive small family farms (Table 3).

The active small family farms achieve the highest revenues due to the high selling price they get. The selling price changes dramatically, from

Table 3. Plot size, yields, prices, revenues, input costs, and profit of Chinese date plantations in different farm types averaged over the period 2010 to 2012

Farm type	Passive small family farms	Active small family farms	XPCC farms	Large commercial farms
Plot area (ha)	0.32	0.90	2.33	4.67
Yield (kg/ha)	512	4030	2363	4209
Price (CYN/kg)	11.87	29.79	16.90	26.46
Revenue (CNY/ha)	6453	121229	46378	109256
Variable costs in sum	1903	19721	21130	16971
Contribution margin (CNY/ha)	4550	101508	25248	92285
Opportunity costs of unpaid Family labor	919	6581	3365	3990
Equivalent annual costs of Fixed assets	459	1700	631	1853
Overhead expenses	0	0	6123	0
Lease	0	40583	0	22794
Profit (CNY/ha)	3180	53255	15584	64279
Contribution margin ratio	71%	84%	54%	84%
Profit ratio	49%	44%	34%	59%
Return to land (CNY/ha)	3180	93839	15584	87072
Return to family labor (CNY/man-hour)	4.62	66.20	33.07	134.15

11.87 CNY/kg in Shaya to 29.79 CNY/kg in Qarqan and Qarklik. It is determined by the date varieties planted and market demand. The highest date yields are attained by large commercial farms at a slightly lower selling price compared to the small family farms.

The best quality Chinese Date is planted in Qarlik and Qarqan in the southern rim of the Tarim Basin. There, the lease for the date orchards is extremely high, up to 40583 CNY/ha. The lease to be paid by the small family farms is nearly the double of the lease to be paid by large commercial farms. Therefore, the producers' costs of the active small family farms are significantly higher that of the large commercial farms. However, the high lease price does not stop people investing in date plantation, because the profit obtained by (active) small family farms with date planting is 30 time as much as the profit obtained with cotton. Large commercial farms have a 20-fold higher profit from date plating compared to cotton planting. Currently, the XPCC farms have the lowest profit rate for date production. However, as told by farmers and experts during the interviews, the date plantation in XPCC farms are still young and the quality of dates is low. As trees grow up, it is expected that the yield and prices will increase.

The variable costs for Chinese Date plantations are in the same range as for cotton plantations. Only the passive small family farms have very low variable costs, as they hardly manage the Chinese Date plantations. Among the variable costs of the active small family farms, XPCC farms, and large commercial farms the largest share is used for fertilizers, followed by seasonal labor costs. The XPCC farms in average spend 9600 CNY per ha for chemical fertilizer, but do not use organic fertilizers, while active small family farms spend nearly 7000 CNY/ha for organic fertilizer and 5500 CNY/ha for chemical fertilizer. Organic fertilizer is considered to increase the quality of dates. In active small family farms and large commercial farms, more organic fertilizer is used than chemical fertilizer, whereas in passive family farms and XPCC farms, almost no organic fertilizer is been used. Only XPCC farms have installed drip irrigation, which is the same for cotton fields. The highest seasonal labor costs (6400 CNY/ha) are spent by large commercial farms, followed by XPCC farms and small family farms (Fig. 4). The passive small family farms in Shaya have no cost for energy and seasonal labor, because the farmers rarely take care of the data trees.

5.3 Pear Cultivation

Tables should be explanatory enough to be understandable without any text reference. Double spacing should be maintained throughout the table, including table headings and footnotes.

Table headings should be placed above the table. Footnotes should be placed below the table with superscript lowercase letters. Pears are planted by small family farms. In the early years of pear plantation, farmers have to use time and monetary resources for planting and fertilizing, without immediate revenues. Pear trees start producing fruit when they are 4 - 5 years old. Afterwards, the yield increases until the trees are 20 years old. The maximum productivity is 45000 kg/ha. Currently, half of the pear trees in the Tarim Basin are 10 to 20 years old so that annual productivity increases yearly. However, as the trees are very sensitive to cold weather and sand storms during flowering and fruit formation, the productivity varies considerably between years. Cold weather in spring and sand storms in 2011 affected the trees during flowering so that the yield dropped to one quarter of the average harvest. Though the market price went up, the profit was negative in that year (Table 4).

Among the variable costs, fertilizer amounts for the biggest share with almost 9500 CNY/ha, followed by seasonal labor costs, pesticides, and packing material (Fig. 5).

5.4 Comparison of the Three Crops

Table 5 presents a comparison between the three crops investigated. The average size of the cotton area per farm was 39.1 ha, over 20 times bigger than the area planted with Chinese Date and pear per farm. Due to the selling price, Chinese Date plantations receive the highest revenue, whereas its variable costs are just as low as that of cotton. Pear has a revenue between cotton and Chinese Date, but the variable costs are higher than of the other two crops. The lease for Chinese Date orchards is extremely high compared to cotton and pear. Only the XPCC farms are exempted from lease, but have to pay overhead fees, which are in the range of pear lease (Table 3 and 5). The highest

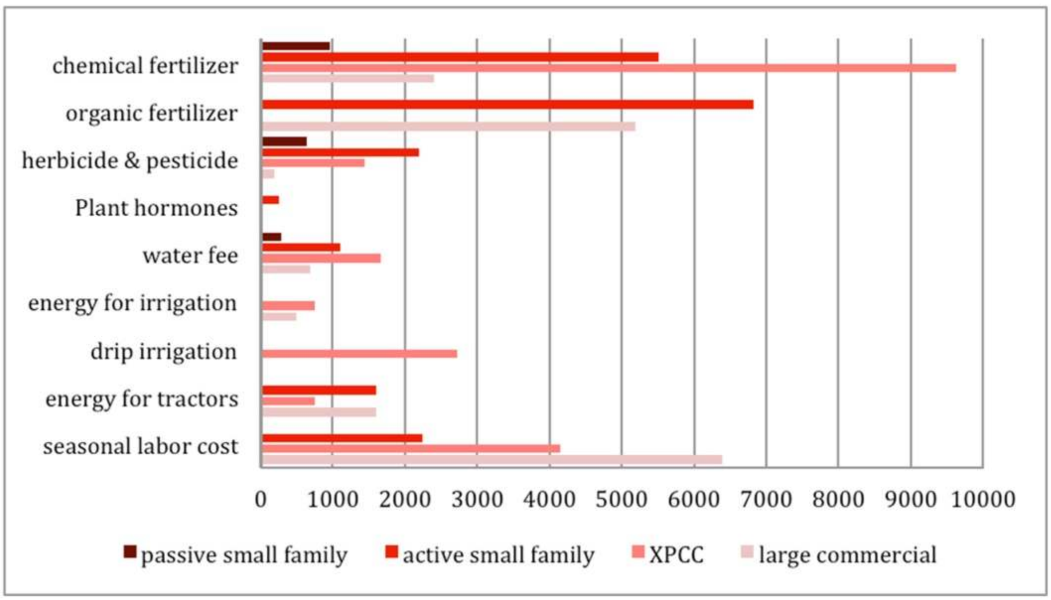

Fig. 4. Variable costs of Chinese Date plantation by farm type averaged over the years 2007 to 2012 [CNY/ha]

Table 4. Plot size, yields, prices, revenues, variable costs, and profit of pear plantations in 2010, 2011, and 2012

Year	2010	2011	2012
Plot area (ha)	1.03	1.74	1.96
Yield (kg/ha)	27642	4879	12695
Price (CNY/kg)	2.81	6.93	5.21
Revenue (CNY/ha)	77778	34328	63252
Variable costs in sum (CNY/ha)	32808	22123	25485
Profit (CNY/ha)	30750	-3262	20099

unpaid labor appears in pear plantation, because works are usually done by family members. Still, the costs for hired seasonal labors are higher than for cotton and Chinese Date.

As a result, among the three land use types, Chinese Date plantations have the highest return to land, followed by pear plantations and cotton plantations. Chinese Date plantations also have the highest return to family labor, but then the return to family labor of cotton plantation is higher than pear plantation.

The variable costs required vary among the three crops investigated (Fig. 5). Cotton is an annual crop, whereas Chinese Date, and pear trees are perennial cultures. Thus, for cotton plantation, seeds and plastic foil are needed annually. Pear plantations require artificial pollination and packing material (plastic bags and nets) to protect the fruit. In cotton plantation and early years of date trees, plant hormones are used, in order to suppress height growth of the plants and in order to enhance branching, respectively. Drip irrigation is installed on a majority of cotton fields and part of the Chinese Date plantations (Fig. 5).

For all three crops, fertilizer and seasonal labor are the two main variable costs. Cotton needs a bit more than half of the chemical fertilizer than date and pear plantations and no organic fertilizer. The highest costs for fertilizers were found for Chinese Date plantations. Pear needs the highest cost for herbicide and pesticide (2970 CNY/ha), which is about 1.6 times of date plantation and 5.5 times of cotton plantation. Pear needs also more water than the other two crops. As a result, we found the highest water fee and energy for irrigation. Water fee does not indicate the amount of water being used. Water fee is determined by the distance of the fields from water sources, and possession of groundwater wells. Due to the fragility of pears, harvesting goes slowly, which results the highest seasonal labor cost (7570 CNY/ha). On the contrary, date harvesting costs 60% lower, because dates are harvested as dry fruit. Cotton requires high seasonal labor costs, too, due to the difficulty of manual cotton picking (Fig. 5). As labor costs rise, machinery cotton harvest is realized on an experimental scale and will be promoted further in the future.

6. DISCUSSION

The cotton yields revealed through the interviews (Tables 1 and 2) correspond well with statistical data from Xinjiang [4]. The cotton yields harvested in the Tarim Basin are the highest yields worldwide as shown in Table 6. Literature research shows that cotton yield in the Tarim Basin is the highest compared to all other areas of the world (see Table 6).

In general, cotton yields are higher, when irrigated under an arid climate, compared to rain-fed cultivation under humid climate [34]. Producers' prices for seed cotton in 2011 were 0.93 USD/kg in Brazil, 0.63 USD/kg in Kazakhstan, and 0.62 USD/kg [5]. The selling prices reported in this study were 8.69 CNY/kg in Table 2 (equivalent to 1.37 USD/kg).

Among the cotton farm types, the XPCC clearly have the highest profits and return to land. This largely can be explained by the high yield harvested by the XPCC farms, the high prices, and thus their high revenues. The XPCC farms are operated by single families, which manage

Table 5. Plot size, yields, prices, revenues, costs, and profit of cotton, Chinese Date, and pear, averaged over the years investigated and farm types, respectively

Crop	Cotton	Date	Pear
Plot area (ha)	39.10	1.76	1.58
Yield (kg/ha)	4482	3437	15072
Price (CNY/kg)	6.73	22.47	4.99
Revenue (CNY/ha)	30637	87615	58453
Variable costs in sum	17234	18446	26805
Contribution margin (CNY/ha)	13402	69169	31647
Opportunity costs of unpaid family labor	1653	4514	6345
Equivalent annual costs of fixed assets	1196	1285	2490
Overhead expenses	2289	2280	608
Lease	1480	15212	6475
Profit (CNY/ha)	6837	46267	15863
Return to land (CNY/ha)	8264	61479	21505
Return to family labor (CNY/man-hour)	56.41	69.18	29.00

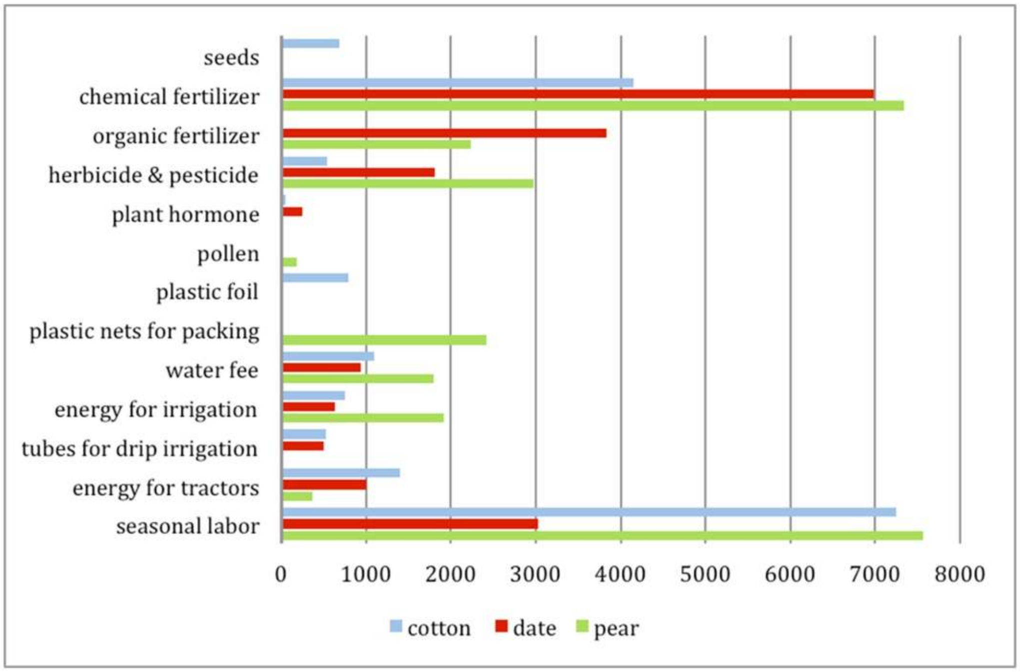

Fig. 5. Variable costs of cotton, Chinese Date, and pear plantation [CNY/ha] averaged over the investigated years and farm types, respectively.

Table 6. Seed cotton yields [kg/ha] reported within this study compared to other cotton production regions of the world

Country	Location	Yield	Year	Source
China		4000	2011	[6]
	Xinjiang	5091	2010	[4]
	Bazhou, Xinjiang	6210	2012	[31]
	Shandong	3000	2011	[6]
USA		2700	2010	[7]
Pakistan		2000	2010	[7]
Turkey		3750	2010	[7]
Uzbekistan	Central Fergana Valley	3600		[32]
Syria	Ras-El-Ain district	4600		[33]
Egypt		2500	2010	[7]
world average		2100	2010	[7]

their field plots more intensively than the large commercial farms. The families belong to a strict organization, the XPCC, which urges the families to plant cotton, but provides extension services, too. The intensive management in combination with high technological standard and good services explains the high yields of XPCC. Furthermore, the interviewed XPCC farms are located in Aral, where water is available all year round. Small family farms are located in villages, where the irrigation infrastructure is less carefully managed than by the XPCC, which is another reason for low yields of family farms. Most large commercial farms are located along the Tarim mid-stream, where periods of water shortage may occur [8,9]. The processing of lint cotton from seed cotton is done within the XPCC system, while large commercial farms and family farms sell their seed cotton to private processing companies. This might explain the price difference between XPCC and the latter two farm types. The large commercial farms are most labor efficient, as their return to family labor shows the highest value among the three farm types. Still, among all three farm types labor costs are the biggest cost item. Under the assumption of rising salaries in China, it is to expect that farmers try to reduce the number of laborers, especially during harvest and shift to harvest machines.

Pear yields in 2011 in Uzbekistan, China, and world average were 7619 kg/ha, 14040 kg/ha, 14728 kg/ha, respectively. The yields reported in this study fluctuated strongly from well above Chinese and world average in 2010 to well below Chinese and world average in 2011. The producers' prices of pears for Algeria, Israel, Jordan, and Turkey in 2011 were 1.26 USD/kg, 1.65 USD/kg, 0.75 USD/kg, and 1.00 USD/kg, respectively [5]. In Xinjiang, the selling price of pears was 6.91 CNY/kg in 2011, equivalent to 1.09 USD/kg, which is in the range of the listed countries.

Cultivation of Chinese Date attains the highest profits, return to land, and return to labor. Even the extensive Chinese Date utilization of the so called passive small family farms attains higher profits and return to land than cotton farming by small family farms. Chinese Date, if harvested in good quality, attains high prices and therefore high revenues. Chinese Date is marketed as a Xinjiang trademark. The two counties Qarklik and Qarqan, which started first to shift from cotton to Chinese Date created a trademark and small family farms there gain high profits and incomes through plantations of Chinese Date. With support in terms of training about planting, grafting, and management, Chinese Date has been an attractive alternative for small family farms. For new plantations, it is necessary to clarify, if market saturation may occur when the trees start to bear fruits.

The pear farms gain higher profits and return to land than small family farms and large commercial farms, which grow cotton. But pears are a less attractive alternative to cotton than dates, because their yields are more sensitive towards weather events than Chinese Date.

Cotton production in the Tarim Basin, though it attains the highest yields worldwide, is not the most profitable crop among the three crops investigated here. Still many farmers do not shift away from cotton. One reason might be that farmers are urged to continue to plant cotton, in order to fulfill requirements of political strategies formulated by the Xinjiang Government. On the other hand it is understandable not to promote Chinese Date and pear all over the Tarim Basin, in order to avoid fast market saturation.

The water demand of cotton is known well. It is also known that cotton farmers face periods of water shortage along the Tarim River. The water demand and vulnerability towards water shortage of Chinese Date is not known yet. If it consumes less water and is more resilient towards water shortage than cotton, Chinese Date should be promoted along the downstream section of the Tarim River, in order to provide a crop, which delivers stable income, even if there is a period of water shortage.

Interviews of this paper indicate that family labor or long-term labor is paid (valued) much lower than short-term labor. In cotton and Chinese Date plantations, large commercial farms employ long-term laborers, who are responsible for field management of a whole production year. At the same time when in need, short-term laborers are hired for ploughing, weed-controlling, pesticide spraying, and harvesting. The market price of short-term laborers ranges from 80 to 150 CNY per day. If the same price was applied for long-term laborers, 6750 CNY/ha would be paid for cotton plantation since 67.5 man-days/ha are needed, and 12000 CNY/ha would be paid for date plantation since 120 man-days/ha are needed (exclude harvesting). However, only 1950-3375 CNY/ha for cotton plantation and 5400-6000 CNY/ha for date plantation are paid for long-term laborers. In the calculation of unpaid family labor of this paper, the market price for short term laborers (80 to 150 CNY per day) instead of the theoretical payment for long-term laborers is applied.

7. CONCLUSION

Among the three crops investigated in this paper, cotton and the fruit trees Chinese Date (*Zyzyphus jujube*) and the local pear variety Korla Fragrant Pear (*Pyrus bretschneideri*), Cultivation of Chinese Date attains the highest profits, return to land, and return to labor. With support in the fields of training about planting, grafting, and management, Chinese Date has become an attractive alternative for small family farms with those being most successful in Qarlik and Qarqan, the counties that started first with Chinese Date. For new plantations, though it is necessary to clarify, if market saturation may occur when the trees start to bear fruits. Pears are a less attractive alternative to cotton than Chinese Date, because their performance is more sensitive towards weather events than Chinese Date.

In the Tarim Basin, the highest cotton yields are harvested worldwide. In the Tarim Basin, the highest cotton yields are attained by the XPCC farms investigated. Those XPCC farms have reliable access to water and apply drip irrigation throughout. Also profit and return to land of the XPCC farms is higher than commercial farms and family farms due to their high yields. Though the XPCC farms are operated by single families, they belong to a strict organization, the XPCC, which urges the families to plant cotton, but provides extension services, too. For all three farm types labor costs amounts for the largest cost. Assuming rising salaries in China, it is to expect that farmers will reduce the number of laborers, especially during harvest, and shift to machine harvest. Farmers along the mid- and down-stream of the Tarim face periods of water shortage and in average lower yields than the XPCC investigated, which all are located upstream.

The water demand and vulnerability towards water shortage of Chinese Date is not known yet and needs further investigation. If it consumes less water and is more resilient towards water shortage than cotton, Chinese Date should be promoted along the downstream section of the Tarim River so that farmers may obtain a stable income, even if there is a period of water shortage.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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