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The importance of agroforestry hay and walnut production in the walnut-fruit forests of southern Kyrgyzstan

Maik Rehnus · Davlet Mamadzhanov · Bronislav Ivanovitch Venglovsky · Jean-Pierre Sorg

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Abstract Walnut-fruit forests (WFF) in Kyrgyzstan are biodiversity hotspots, provide important ecosystem services, and are of economic value yet currently suffer from a lack of sustainable management. We analysed current agroforestry practices through a series of interviews with farmers and reviewed the input–output data for 5 years of hay and walnut production for three case studies. The interviews showed that hay-making and walnut collection are the primary agroforestry practices in the WFF and have clear economic importance. Walnut in particular is a source of additional income for farmers and hay-making activities are strongly influenced by the need to winter cattle in these regions. The low reliability of interview data limited the planned analysis of profitability of case studies. Walnut production, however, is difficult to calculate because it is highly dependent on weather conditions and cropping practices between walnut trees (*Juglans regia* L.). This study highlights the need for improved agroforestry technologies in the WFF and identifies potential means for a sustainable, multi-purpose management of the WFF with a special focus on income generation.

Keywords Profitability analyses · Interview reliability · Agroforestry case studies · *Juglans regia* · Tree-crop interactions

M. Rehnus (✉) · J.-P. Sorg
Groupe de foresterie pour le développement, Department of Environmental Sciences, ETH Zurich, Zurich, Switzerland
e-mail: maik.rehnus@env.ethz.ch

D. Mamadzhanov
Laboratory of Forest Resources, Forest Research Institute, Bishkek, Kyrgyzstan

B. I. Venglovsky
Fund "Forest Protection", Bishkek, Kyrgyzstan

Introduction

Kyrgyzstan is one of the most sparsely forested countries in Asia with only 6.97 % forest cover (Grisa et al. 2008). Unique forests of walnut (*Juglans regia* L.) and other fruit-bearing tree species grow in the southern part of Kyrgyzstan. These forests are considered a biodiversity hotspot (Fisher and Christopher 2007) and therefore have international significance as a genetic pool for many tree (Mamadjanov 2006; Venglovsky 2006). The current area of walnut-fruit forests (WFF) is 47,000 hectares (Grisa et al. 2008) of which large areas are in critical condition and are not very productive (Müller and Sorg 2001; Scheuber et al. 2000; Venglovsky 2006). The need for multifunctional management approaches that involve local communities is urgent (Müller and Sorg 2001; Rehnus and Sorg 2010).

After Kyrgyzstan gained independence in 1991, much of the country's Soviet-era infrastructure broke down including its industry, public services and governmental administration. The WFF in particular became essential to the local population as a multipurpose resource for walnuts, fruits, fuel wood, hay, pastures, and other non-timber products (Messerli 2002; Scheuber et al. 2000; Schmidt 2007; Schmidt 2005). As a result, importance of the primary sector for food and energy security increased in a time of economic and social hardship and resulted in conflicts with the established conservation-oriented forest policy (Schmidt 2007). The WFF are owned by the state and managed by the state forest service. Due to the increased pressure on these forests for products their sustainable management is no longer ensured (Venglovsky et al. 2010).

Agroforestry, a land-use practice which combines woody perennials with crops and/or animals on the same land management unit (Nair 1993), is one way of using WFFs for multiple purposes. Sound agroforestry practices can provide food security, enhance soil fertility, enhance biodiversity, conserve soil and water, supply fodder and enable income generation by ensuring a diversity of outputs (Garrity 2004; Huxley 1999; Jose 2009; Nair 1993; Nair 2007). Agroforestry practices with *Juglans regia* can be found from Europe to Central Asia while similar practices mostly use *Juglans nigra* in North America. Both species are important in their respective countries for creating biodiversity within agroforestry practices (Gray 2006; Jalilova 2007; Rehnus et al. 2011). The main aim for European farmers from an agroforestry plot with walnut is providing both timber and nuts combined with an intercropping system (Dupraz et al. 1999; Mary et al. 1998; Newman 2006). Studies conducted in Europe have shown that walnut fruit, timber and intercropping production can be increased by various agroforestry activities and that over time the income of the farmers increased (Dupraz et al. 1999; Magagnotti et al. 2011; Mary et al. 1998; Newman 2006; Oosterbaan et al. 2006; Pini et al. 1999). In Kyrgyzstan the aims are concentrated on nuts and intercropping only because timber production is limited by the Kyrgyz Forest Codex. Agroforestry practices in the WFF, their profitability, and plant interaction associated with production of agroforestry products are not well described in the literature. It is clear that the multifunctional production of WFF in southern Kyrgyzstan suffers from a lack of management (Messerli 2002; Rehnus and Sorg 2010; Schmidt 2005). The same forest plot is often used by multiple people gathering different forest products, a condition that has resulted in conflict and forest degradation.

An understanding of current agroforestry activities will play a major role in determining sustainable agroforestry practices in the WFF. We therefore studied (i) general agroforestry practices and the current state of farmers' knowledge and (ii) analysed the productivity and economic importance of hay and walnut harvests over the course of 5 years from three case studies.

Materials and methods

Study area

The study was conducted in three neighbouring state forests in Ortok (N41°12′; E73°14), Kaba (N41°17′; E72°48) and Arslanbop (N41°20′; E72°55) at 1,200–1,800 m.a.s.l. (Fig 1). These forests are mainly used for agroforestry and are located in the Fergana–Chatkal forest growth region on the southwestern slopes of the Fergana and Chatkal ridges of the Tien-Shan mountain range. Mountain ridges to the north, east and south protect the entire Fergana valley against the flow of cold air from the north (Venglovsky 2006). The climatic conditions are favourable to WFF growth, with sufficient precipitation (up to 1,090 mm/year), moderately warm summers with an average July temperature of +20.5 °C, and mild winters with an average January temperature of −3.1 °C (Grisa et al. 2008).

Palynological results showed that the walnut-fruit forests originated only 1,000–2,000 years BP in their present appearance and that they had very likely been established as a consequence of human land use (Beer et al. 2008). Over the last several centuries, humans

Fig. 1 Distribution of the walnut-fruit forests in Kyrgyzstan with main occurrence in the Fergana–Chatkal forest growth region and location of the study area (map by Grisa et al. 2008, adapted)

have influenced and modified the WFF by planting selected species and varieties, grafting productive stock to less productive species and by using some of the forest area as grazing grounds and for tillage (Schmidt 2007). As a result the WFF are now a rich cultural landscape composed of a mosaic of natural and planted forest stands, field, pastures and drier open areas.

Different models exist for leasing agroforestry plots in the WFF depending on land and forest tenure. Leases can cover a few weeks to multiple years for a single or multiple products depending on the product and harvest arrangements. As a result, the same plot is often used by several different people for gathering different forest products leading to conflicts of interest between the local people and restricts the ability of the state to plan for multifunctional uses (Rehnus and Sorg 2010).

Data collection

Agroforestry practices

To gain a qualitative overview of agroforestry practices related to walnut trees in WFF, 19 semi-structured interviews (SSI) with randomly selected farmers were conducted on their agroforestry plots in Arslanbop ($N = 9$), Kaba ($N = 7$), and Ortok ($N = 3$) between March and October 2006. Based on the complex systems of lease models, it is not possible to statistically determine what percentages of the farmers in the study areas utilized agroforestry practices, so we selected those farmers who managed for both hay and walnut from a single plot. The guidelines for the interview on local knowledge and agroforestry practises included closed as well as open-ended questions to start an open discussion with the farmer. The selection of farmers was conducted during field work when (i) farmers were on their plots and (ii) when farmers had time for an interview. SSI is a cost-effective approach for collecting existing knowledge from farmers and a well-established research method for analyzing agroforestry practices (Berenschot et al. 1988; Fischer and Vasseur 2002; Romer 2005; Thapa et al. 1995; Walker et al. 1995) and is well established in the study area (Schmidt 2007). Information about how farmer households make decisions regarding the use and management of agroforestry products and about their knowledge of competition between trees and crops were gathered. Furthermore, farmers were asked about sociodemographic information (age, family members, livestock), plot size, the occurrence of different products (yes/no), the proportion of each agricultural product on a plot (%), and the number of walnut, apple (*Malus* sp.), plum (*Prunus* sp.) and other trees. Livestock was tabulated at the total head of cows, horses, sheep and goats with assumption that a higher number indicates a higher level of living. All interviews were conducted by a native Kyrgyz, in Kyrgyz/Uzbek (the native languages in study area), with responses translated to Russian and then to English at the time of data entry. To show the importance of different products between different agroforestry practices, we determined the mean proportion of each agricultural product (%) and the mean number of all trees per ha and the mean number of walnut trees per ha (N/ha; data sheet for plot 13 was lost during field work) for each representative practices of hay-walnut, hay-walnut-fruit, and hay-walnut-fruit-crops based on the 19 agroforestry plots.

Case studies

To quantify the economic importance of hay and walnut in the WFF, the practices of three farmers (F3, F4, and F14) were selected and developed into case studies for the three agroforestry practices. We estimated input/output production data at each plot twice a year from 2006 to 2010. From May to June each year, input data (e.g. time investment in preparing fields, caring for trees) were estimated, while from August to October output data were determined (production volume) and remaining input (harvest time). A total of 30 interviews were conducted with the farmers of selected plots twice a year over a period of 5 years. Farmers were informed that the purpose of the interviews were to collect data to study input/output data of their agroforestry plots. Standardized questions were used based on Altwegg (2003). Prior to interviews in the field, the interviewer was introduced to the research topic and instructed about how to conduct an interview. Unfortunately, team changes could not be avoided over the five-year period; as a result, interviews were conducted by three different people over the course of this research.

Studies should be designed such that the various kinds of errors inherent in interview data can be estimated (Fleiss 1970). We tested the reliability of our recorded interview data by checking farmers' estimates of production against the measured production of walnut (kg/ha) and hay (kg/ha) for each field.

We used both walnut and hay for testing because hay-making activities are widely established in the WFF and because walnut often represents a significant proportion of the annual income of a farmer (Altwegg 2003; Matter 2005).

Measurements from May to June and from August to September by the geobotanical research group for the ORECH-LES project were used to estimate hay production in 2006 to 2009. Hay was cut from three to five 1-square meter plots set along transects through the three representative agroforestry practices and air-dried before weighing. We visually estimated yield of each walnut trees on a plot using an established 4-point scale which indicate expected yields of nuts depending on its age and finally, we summarized all yields of walnut trees per hectare for each practice. Although firewood is also an important product from these forests (Rehnus et al. 2012; Schmidt 2005), we had to exclude it from analysis due to irregular harvest records.

For the description of input data, we estimated the annual time expenditure as work days/ha for each activity. For hay production input, we considered the days spent preparing fences, clearing plots, directing water and harvesting. Time used caring for tree and for harvesting walnuts were the main input factors considered for walnut production. Transport costs were not included, as the goal was to illustrate site-based input/output activities only. For the output data per year, we determined the informative value of our collected interview data per tenant and year by comparing estimated annual production of hay and walnut with field measurements (for hay from 2006 to 2009 and for walnut from 2006 to 2010). For annual profitability analyses, the average daily cost for time was 50, 50, 100, and 250 Som/day (1 US\$ = 46.4 Som) for 2006–2009, respectively. Likewise, price for hay was 5.25, 3.5, 5.0 and 5.0 Som/kg and price for nuts was 50, 50, 50, and 70 Som/kg for 2006–2009 respectively.

Results

Agroforestry practices

Plot size and combination of agricultural and tree products

The plot sizes for the 19 interviewed farmers ranged from 0.3 to 15.0 ha (Table 1). Various combinations of agricultural and trees products were present at these plots in different quantitative proportions. For all studied agroforestry practices, we found hay-making to be an essential activity, consuming the highest proportion of area for all plots (87.0 ± 5.3 %). At most plots, walnut trees had the highest number of stems per hectare compared to apple and plum trees but not to other tree species.

Decision making for agroforestry products

Of the 19 farmers interviewed, 12 farmers said they selected agricultural products based first on their family's needs, then according to environmental conditions (four farmers) and income generation (three farmers). The same order of importance was observed for tree products (nine farmers cited family consumption as their first criteria; five farmers each cited environmental conditions and income generation).

Knowledge of competition between trees and crops

Farmers were also questioned about their observations on crop-tree interactions. 15 farmers observed an influence of the tree crown size on crop production, 14 farmers noted an influence due to tree roots and 11 farmers said leaves significantly influence crop production. The interviews revealed that most farmers were aware that the shadows cast by the crowns slowed the soil moisture lose during hot weather periods. The competition between trees and crops for light was also mentioned. Farmers identified tree roots as the greatest challenge to their agroforestry practices because the presence of large roots makes field preparation difficult. With regard to these effects, 14 farmers identified differences between tree species, noting that walnut trees have larger crown and root systems than fruit and other trees. Therefore walnut trees have a greater influence on total production compared to fruit and other tree species. Interviewees noted that the distance between walnut trees and agricultural products is typically about 10.1 ± 1.8 m (range 2.0–20.0 m), while for other tree species the distance is 5.1 ± 1.2 m (0.2–15.0 m).

Only four farmers managed their agroforestry plots by pruning trees in order to increase productivity. Ten farmers did not prune at any time and five farmers did not give an answer to this question. Farmers indicated that they received most of their knowledge about new

Table 1 Sociodemographic information for famers' age, number of family members and head of livestock, area of agroforestry practice (ha), proportion of land area in hay and other crops, and average number of trees by type per hectare for the 19 farmers (F1-F19) practicing hay-walnut agroforestry in Kyrgyzstan

Agroforestry practice	Hay-walnut				Hay-walnut-fruit					
Product/farmer	F1	F2	F3	Mean ± SE	F4	F5	F6	F7	F8	Mean ± SE
Sociodemographic information										
Farmers' age	37	57	54	49.3 ± 6.23	76	64	55	39	64	59.6 ± 6.14
Family members	4	6	5	5.0 ± 0.58	7	8	5	5	10	7.0 ± 0.95
Livestock	–	–	–	–	6	18	–	7	8	9.8 ± 2.78
Area (ha)	0.6	0.3	0.5	0.5 ± 0.11	0.8	0.6	0.6	0.5	1.0	1.6 ± 0.85
Agrocultures (%)										
Haymaking	100.0	100.0	100.0	100.0 ± 0.0	100.0	100.0	100.0	100.0	100.0	100.0 ± 0.0
Potatoes	0.0	0.0	0.0	0.0 ± 0.0	0.0	0.0	0.0	0.0	0.0	0.0 ± 0.0
Lucerne	0.0	0.0	0.0	0.0 ± 0.0	0.0	0.0	0.0	0.0	0.0	0.0 ± 0.0
Maize	0.0	0.0	0.0	0.0 ± 0.0	0.0	0.0	0.0	0.0	0.0	0.0 ± 0.0
Sunflower	0.0	0.0	0.0	0.0 ± 0.0	0.0	0.0	0.0	0.0	0.0	0.0 ± 0.0
Barley	0.0	0.0	0.0	0.0 ± 0.0	0.0	0.0	0.0	0.0	0.0	0.0 ± 0.0
Other	0.0	0.0	0.0	0.0 ± 0.0	0.0	0.0	0.0	0.0	0.0	0.0 ± 0.0
Trees (N/ha)										
Walnut	183	184	119	162 ± 22	162	122	67	160	100	122 ± 18
Apple	0	0	0	0 ± 0	126	117	202	20	0	93 ± 37
Plum	0	0	0	0 ± 0	5	48	235	0	0	58 ± 45
Other trees	0	0	0	0 ± 0	30	8	77	14	25	31 ± 12

Agroforestry practice	Hay-walnut-fruit-crops											
Product/farmer	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	Mean ± SE
Sociodemographic information												
Farmers' age	54	48	43	73	35	22	48	32	47	55	38	45.0 ± 4.09
Family members	10	6	6	7	4	3	8	3	6	4	9	6.0 ± 0.71
Livestock	15	37	2	1	5	13	6	7	17	3	4	10.0 ± 3.15
Area (ha)	15.0	3.0	3.0	1.0	2.0	1.8	2.0	0.5	0.6	1.3	1.4	2.9 ± 1.24
Agrocultures (%)												
Haymaking	99.9	93.8	91.0	90.0	90.0	87.2	80.0	77.5	75.0	69.4	10.0	78.5 ± 7.37
Potatoes	0.1	0.0	0.0	5.0	2.5	3.5	5.0	2.5	0.0	1.7	0.0	1.8 ± 0.6
Lucerne	0.0	1.7	0.0	0.0	0.0	9.3	0.0	20.0	0.0	12.4	35.7	7.2 ± 3.5
Maize	0.0	0.0	0.0	5.0	2.5	0.0	5.0	0.0	25.0	0.0	0.0	3.4 ± 2.24
Sunflower	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	27.1	2.9 ± 2.46
Barley	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.1	2.9 ± 2.46
Other	0.0	0.0	9.0	0.0	0.0	0.0	10.0	0.0	0.0	16.5	0.0	3.2 ± 1.76
Trees (N/ha)												
Walnut	77	10	33	160	-	66	33	30	20	37	34	50 ± 14
Apple	0	43	0	0	-	67	0	0	17	57	0	18 ± 8
Plum	0	0	0	0	-	49	0	0	17	47	0	11 ± 6
Other trees	613	231	167	160	-	208	401	344	135	316	0	257 ± 54

agroforestry technologies from research projects (nine farmers), forest specialists (six farmers), ancestors/relatives (three farmers), and neighbours/friends (one farmer). None of the farmers indicated they acquired their knowledge through the local schools.

Case studies

To quantify the economic importance of hay and walnut in the WFF, the practices of three farmers (F3, F4, and F14) were selected and developed into case studies for the three agroforestry practices (Table 2). After comparing the interviews and field data (3 plots over 5 year), we found no correlation between perceived and measured hay production ($r = 0.21$, $p = 0.496$). Annual differences per year between the farmers' perceptions and the measured values ranged from 0.5- to 2.3-fold (1.6 ± 0.4 fold). For walnut production, we found a weak correlation ($r = 0.50$, $p = 0.066$) with differences ranging from 0.3- to 1.4-fold (0.8 ± 0.2 fold). As a consequence, only the field measurements determined by the geobotanical group were used to calculate the profitability of hay and walnut per plot.

Input data

The average annual time expenditure for hay production was 21.7 ± 3.0 work days/ha. The highest proportion of time was spent rebuilding the plot fences (98.1 ± 1.9 %). We found the highest annual time expenditure for hay production in the hay-walnut-fruit-crops practice (28.5 ± 5.2 work days/ha), followed by the hay-walnut-fruit practice (24.3 ± 4.6 work days/ha) and, finally, the hay-walnut practice (12.3 ± 2.8 work days/ha) (Fig. 2a). The average annual time expenditure for walnut production was 18.8 ± 3.1 work days/ha; correspondingly, tree care was found to be the least time-demanding (5.1 ± 3.0 %) activity. The highest time expenditure was again in the hay-walnut-fruit-crops practice (25.2 ± 3.5 work days/ha), followed by the hay-walnut-fruit practice (20.6 ± 7.0 work days/ha) and, finally, the hay-walnut practice (10.6 ± 3.3 work days/ha) (Fig. 2b).

Output data

The highest annual hay production was in the hay-walnut-fruit practice (1068 ± 71 kg/ha), followed by the hay-walnut-fruit-crops practice (638 ± 55 kg/ha) and, finally, the hay-walnut practice (504 ± 33 kg/ha). The year with the highest hay production was not constant between the three plots (2006 in hay-walnut and hay-walnut-fruit-crops practices with 565 kg/ha and 800 kg/ha, respectively; 2009 in hay-walnut-fruit practice with 1,200 kg/ha). The year of lowest production for all three plots was 2008 (Fig. 3a). Yearly changes in hay output ranged up to 1.5-fold on a single plot over several years. The highest measured walnut output was found in the hay-walnut-fruit-crops practice (180 ± 20 kg/ha), followed by the

Table 2 Characteristics of three representative agroforestry practices in Kyrgyzstan

Parameter	Hay-walnut	Hay-walnut-fruit	Hay-walnut-fruit-crops
Altitude (m a.s.l.)	1,750	1,600	1,530
Aspect	S	SE	NE
Slope (°)	10–15°	20–25°	10–15°
Soil	Brown ground	Brown ground	Black-brown
Size (ha)	0.54	0.81	1.83
Area for haymaking (ha)	0.52	0.78	1.5
Area for agrocultures (ha)	–	–	0.22
Number of all trees (N/ha)	131	417	215
Mean dbh of all tree (cm)	23.6	10.7	14.6
Crown projection of walnut (m^2/ha)	6,549	5,725	6,334
Number of walnut tree (N/ha)	131	185	67
Mean dbh of walnut tree (cm)	23.6	15	37
Mean height of walnut tree (m)	10.2	6.1	13.4

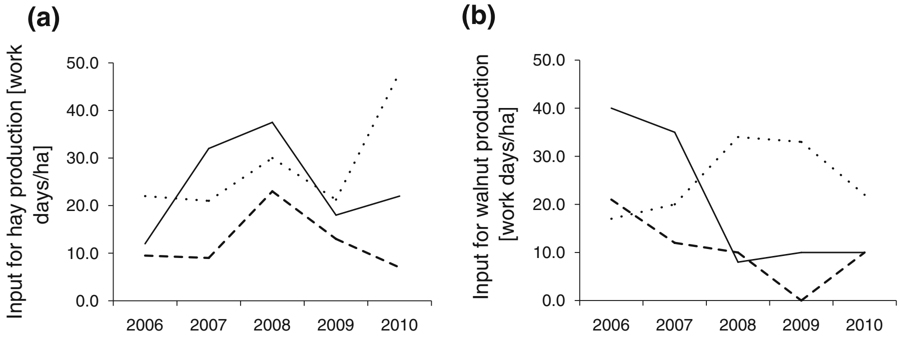

Fig. 2 Time expenditure (work days/ha) for **a** hay production from 2006 to 2009, and **b** walnut production from 2006 to 2010 in hay-walnut (*dotted line*), hay-walnut-fruit (*solid line*), and hay-walnut-fruit-crops practice (*dashed line*)

hay-walnut practice (114 ± 43 kg/ha) and in the hay-walnut-fruit practice (74 ± 14 kg/ha). Again, the year of highest production was not the same for the three plots: 2010 was the year of greatest production in the hay-walnut-fruit practice and in the hay-walnut-fruit-crops practice (122 kg/ha and 246 kg/ha, respectively) whereas 2006 was the year of highest production in the hay-walnut practice (253 kg/ha). Lowest production values occur in year 2007 in the hay-walnut-fruit practice and in the hay-walnut-fruit-crops practice (43 kg/ha and 125 kg/ha, respectively) and in 2009 in the hay-walnut practice (0 kg/ha; Fig. 3b). Yearly changes in walnut production ranged from failed harvests up to 253 kg/ha on the same plot over several years.

Profitability analysis

Finally, the calculation of profitability for each plot including hay and walnut production showed a constant positive value over the observed time period (Fig. 4). In the hay-walnut-fruit practice we estimated the highest annual profit from hay production (5,670 ± 750 Som/ha), followed by the hay-walnut practice (4,220 ± 447 Som/ha) and, finally, in the hay-walnut-fruit-crops practice (651 ± 228 Som/ha). The highest annual profit from walnut production was found for the hay-walnut practice (9,210 ± 480 Som/ha), followed by the hay-walnut-fruit-crops practice (3,150 ± 330 Som/ha) and, finally, in the hay-walnut-fruit practice (2,680 ± 593 Som/ha).

Discussion

Decision making for agroforestry products

We observed that agroforestry products are mostly selected for family consumption and are therefore of particularly high importance. While agricultural and tree products are ranked similarly in terms of importance, tree products seem to have a higher importance

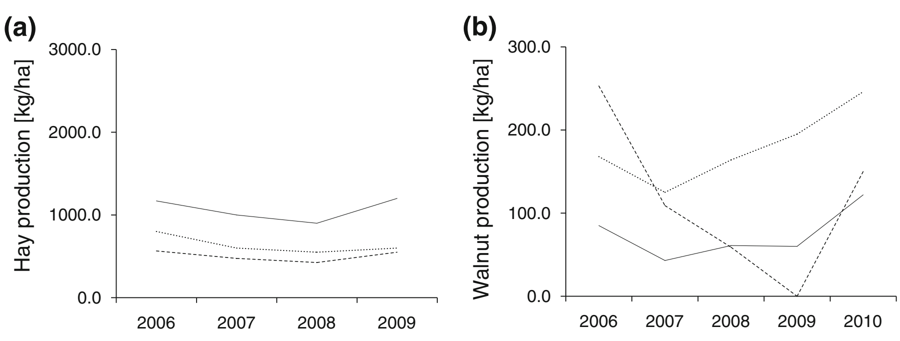

Fig. 3 **a** Hay production (kg/ha) from 2006 to 2009, **b** walnut production (kg/ha) from 2006 to 2010 in hay-walnut (*dotted line*), hay-walnut-fruit (*solid line*), and hay-walnut-fruit-crops practice (*dashed line*)

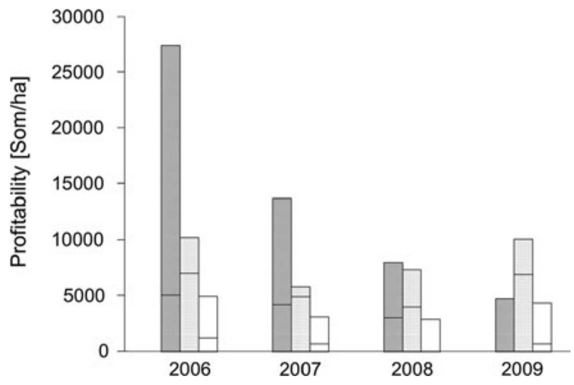

Fig. 4 Profitability from 2006 through 2009 calculate from input/output data for hay (*lower proportion*) and walnut (*upper proportion*) from in hay-walnut (crosshatched), hay-walnut-fruit (*dotted*), and hay-walnut-fruit-crops practice (*open*) in Kyrgyzstan (1 US$ = 46.40 Som)

for income generation compared to agricultural products which have higher importance for family's need. Field observations and the analysis of plot composition both indicate that hay-making is the most important agroforestry activity in the WFF. Hay-making requires large areas because of its low productivity under forest cover (Juldashev and Messerli 2000). The area suitable for hay-making is limited by afforestation activities, rocky and/or steep conditions, and pressure to use hay meadows for other agricultural products. Hay-making is therefore often relocated to more distant areas, thereby incurring higher transport costs (Messerli 2002; Scheuber et al. 2000). However, hay activities have a negative influence on the natural regeneration of the WFF. When hay is harvested, for example, young saplings from walnuts and other trees are inadvertently cut. As a result, WFFs suffer from insufficient regeneration (Venglovsky 1998).

While walnut and hay are the primary agroforestry products in WFFs, composition analysis also showed that approximately half of farmers planted crops at suitable places in the forests for personal consumption. The low proportion of these crops, however, is an indication of limited land resources. The interviews also revealed a limited access to knowledge about new agroforestry technologies (e.g. cropping between trees), which leads to limited or inefficient agricultural activities. Interviews revealed that nearly half of all farmers received information about agroforestry from research projects such as the ones described in this paper. Organized seminars for local farmers to introduce them to agroforestry practices and expected economic gains using multi-use approaches have been found to be highly effective.

The analysis of tree products emphasized the importance of fruits—especially from walnut—in the WFFs. But walnut trees produce not only a nut crop that can be used for personal consumption and income generation and also valuable lumber. However, logging of trees and especially of walnut trees for lumber production is limited by the Kyrgyz Forest Codex and by administration rules such that farmers have no incentive to improve quality of the trees. Thus the economic value of walnut trees is therefore based primarily on nut production.

In addition to the monetary benefits of walnut production, the importance of apples as a source of income was indicated, though not studied specifically in this work. Juldashev and Messerli (2000) suggested that the apple is the most common orchard tree in the WFF area. This may be the result of its importance for family consumption and/or additional income from market sales, or deliveries to factories near the WFFs (Martin and Jalilova 2000).

Knowledge of competition between trees and crops

By definition, agroforestry depends on the successful integration of trees and crops on the same unit of land. Although walnut roots make field preparation difficult, the interviews showed that farmers are aware that walnut trees can have positive and negative influences on other products in the agroforestry plots. Drossopoulos et al. (1996) and Frak et al. (2006) indicated that leaves increase nutrient availability in soils. Juldashev and Messerli (2000) found that the shadows of walnut trees reduce micro-climate extremes and, in dry climate conditions, reduce temperature and moisture oscillations, leading to better plant growth conditions. Hemery (2001) reported that walnut trees benefit from being planted in mixed stands, particularly with nitrogen-fixing species. Orchard grass (*Dactylis glomerata* L.) and red clover (*Trifolium pratense* L.) have been shown to benefit from applications of the husks of walnut (Houx et al. 2008) and we assumed that husks can increase hay production in agroforestry practices in the WFF, too. However, Persian walnut trees are light-demanding and have large crown diameters (Venglovsky 2006), as well as an allelopathic reaction that negatively influences the growth of other species (Willis 2000).

Case studies

Reliability of our recorded interview data

The comparison between interview estimates and field measurements of outputs has shown no or only low correlations. The validity of the interview data is highly influenced by the ability and willingness of the respondent to provide accurate information (Fischer 1998). The observed inconsistencies may also be the result of personnel changes in the interviewing team over the 5 years of the study resulting in inconsistent interview procedures and/or language barriers that led to distortions and information loss (Juldashev and Messerli 2000). One interviewer also noticed that farmers mistakenly assessed products cultivated on other plots (Sorg 2007). We also observed differences in correlations between interview data and field measurements with differences for hay as a non-market and walnut as a market product. The estimates of the production of marketable products correlated well with measured values but the correlation was much lower for non-market products. For market products with economic importance (e.g. market sales), the difference between measurements and interview data was better correlated than for non-market products. A possible explanation could be that knowledge about income generation is more important for farmers than knowledge about personal consumption. In particular, we found that farmers generally overestimated hay production, which can be explained by farmers mistakenly assessing hay cultivated on other plots, as previously mentioned. Similar over- and underestimates were also found in other studies using a mix of interviews and measurements (Fox 1984; Marsinko et al. 1984; Pomerleau et al. 2003). We recommend that future studies employ a careful research design, a higher number of respondents and use field measurements for agroforestry surveys assessing production and economic importance.

Input data

Detailed analysis of the time expenditure required for hay and walnut production showed a high investment in rebuilding fencing for hay and a low investment in tree care. During field work, we observed that in late summer or autumn, fences of agroforestry plots were opened for cattle grazing or destroyed during firewood collection. Thus, a yearly investment for new fencing is necessary. The low investment in tree care can be explained by limited access to new knowledge about agroforestry technologies and that walnut trees older than about 25 years typically do not require much annual care. It is also important to note that the forest is state-owned; because activities such as tree care require official permission, farmers spend little time maintaining the trees. In addition, farmers may be unwilling to invest in long-term tree management when land is leased under short term contracts or even multiple contracts for the different products coming from the same fields.

Output data

We used only field measurements from another research group for hay and walnut production because of the lack of reliability in the interview data. The highest annual hay production was in the hay-walnut-fruit practice where the crown projection of walnut is low (5,725 m^2/ha); in comparison production in the hay-walnut practice (6,549 m^2/ha) and in the hay-walnut-fruit-crop practice (6,334 m^2/ha) is notably lower for all years. The lowest and highest hay production values for all plots generally occurred in the same years, which indicate the dependence of production on weather conditions. While both factors influence hay production, the relatively small changes in walnut tree crown size and climate ensure a fairly stable income over time. In contrast, income generated from walnut trees is difficult to predict, namely due to the threat of late frosts (Venglovsky 2006). In years with at least moderate walnut production, the income generated from sales of walnut products can be important for farmers (Schmidt 2007). Furthermore, fire blight (*Erwinia amylovora*) and insect pests including *Lymantria dispar*, *Speralecanium prunestri*, *Calioria prunastru*, *Eulacanus prunastrucan*, and *Crysomeliolae* can significantly reduce production of fruit-bearing trees in the WFF (Alkanov 1998). Fire blight leads to a slow decline in fruit production and death of the tree while insect pests are more cyclic and dependent on the environment. The analysis of walnut production in southern Kyrgyzstan has also shown that a large crown positively influences the production of walnut per tree (Venglovsky et al. 2010). In our study the hay-walnut-fruit practice had the highest hay production and the lowest production of walnuts due to smaller crown project per hectare. Such correlations are well-described (Venglovsky 2006). As shown in the hay-walnut practice, large changes in walnut production over time indicate a high dependence on weather conditions and for example, due to late frost walnut production failed completely in 2009 there.

Profitability analysis

The analysis of hay and walnut production and of plot profitability revealed marked differences between plots. Differences in the production of walnut (Fig. 3b) due to weather conditions make it difficult to calculate annual plot income. In hay-walnut practice, it was shown that a lower production and thus a reduced output of one product will lead to a higher dependence on another product in the same year. However, higher product diversity reduces the risk of production failure in an agroforestry plot (Huxley 1999; Nair 2007) and has considerable economic and environmental advantages over more simple farming systems (Gordon and Newman 1997). The hay income is more constant over years and seems to be a more calculable income which is important for the wintering of cattle. Other studies investigated walnut plantation suggested also that walnut trees have a low net income for the first years as result of initial investment, protection against animals and missing production (Newman 2006; Oosterbaan et al. 2006). However, a complete profitability analysis of a single agroforestry plot could not be conducted as result of mentioned lack of reliability of interview data. Also the case studies are a study of one field and there is no replication. In this way we suggest a complete analysis by field measurements of all products or analysis of a whole farmers' family household for future agroforestry investigation in this study area.

Long-term management

As hay and walnut production depend on crown volume for opposite reasons, a demanding management plan is needed with regard to increasing the long-term production of both products. For example, unproductive walnut trees can be specifically managed to increase the crown size of neighbouring walnut trees, or replaced with hay meadows. However, such short-term benefits must be balanced with natural regeneration or planting to ensure sustainability of multi-purpose production. Such management requires the knowledge and interest of farmers if it is to work over the long-term.

Conclusion

Our overview of agroforestry practices in the WFFs in southern Kyrgyzstan by means of interviews and case studies indicates the high importance of hay-making and walnut production for farmers. Hay is important for the wintering of cattle and walnut production is an important source of income. The production of both hay and walnut varied over the years depending on weather and plot peculiarities. The study shows a lack of forest management and indicates a high need for improved agroforestry education and technologies for both government officials and local households. The use of all products from a single plot by one farmer or household should meet the needs of the farmers and the installation of more long-term leasing models should be met with sustainable management plans. Future improvements in agroforestry will rely on continuing education about new agroforestry technologies, on the multiple-use approach and on exchange of experience and knowledge amongst farmers and workers in state forests.

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References

Alkanov DJ (1998) Forest health and forest protection measures in walnut-fruit forests of southern Kyrgyzstan. In: Blaser J, Carter J, Gilmour D (eds) Biodiversity and sustainable use of Kyrgyzstan's walnut-fruit forests. IUCN, Gland; Intercooperation, Berne, pp 97–98

Altwegg J (2003) Probeflächen von Orech-Les in den Waldnussfruchtwäldern im Süden Kirgistans. ETH, Zurich, pp 1–41

Beer R, Kaiser F, Schmidt K, Arnmann B, Carraro G, Grisa E, Tinner W (2008) Vegetation history of the walnut forests in Kyrgyzstan (Central Asia): natural or anthropogenic origin? Quaternary Sci Rev 27:621–632

Berenschot LM, Filius BM, Hardjosoediro S (1988) Factors determining the occurrence of the agroforestry system with Acacia-mearnsii in Central Java. Agrofor Syst 6:119–135

Drossopoulos B, Kouchaji GG, Bouranis DL (1996) Seasonal dynamics of mineral nutrients and carbohydrates by walnut tree leaves. J Plant Nutr 19:493–516

Dupraz C, Simorte V, Dauzat M, Bertoni G, Bernadac A, Masson P (1999) Growth and nitrogen status of young walnuts as affected by intercropped legumes in a Mediterranean climate. Agrofor Syst 43:71–80

Fischer A (1998) Integrating rural development and conservation: the impacts of agroforestry projects on small farmers in Panama. Dalhousie University, Nova Scotia, pp 1–268

Fischer A, Vasseur L (2002) Smallholder perceptions of agroforestry projects in Panama. Agrofor Syst 54:103–113

Fisher B, Christopher T (2007) Poverty and biodiversity: measuring the overlap of human poverty and the biodiversity hotspots. Ecol Econ 62:93–101

Fleiss JL (1970) Estimating reliability of interview data. Psychometrika 35:143–162

Fox J (1984) Firewood consumption in a Nepali village. Environ Manage 8:243–249

Frak E, Le Roux X, Millard P, Guillaume S, Wendler R (2006) Nitrogen availability, local light regime and leaf rank effects on the amount and sources of N allocated within the foliage of young walnut (*Juglans nigra* × *regia*) trees. Tree Physiol 26:43–49

Garrity DP (2004) Agroforestry and the achievement of the millennium development goals. Agrofor Syst 61–2:5–17

Gordon AM, Newman SM (1997) Temperate agroforestry. CAB International, Wallingford, pp 1–269

Gray BS (2006) The amphibians and reptiles of the Asbury Woods Greenway, Erie County, Pennsylvania. Bull Md Herpetol Soc 42:115–126

Grisa E, Venglovsky BI, Sarymsakov Z, Carraro G (2008) Forest typology of the Kyrgyz Republic. Intercooperation, Bishkek, pp 1–217

Hemery GE (2001) Growing walnut in mixed stands. Quart J Forestry 95:31–36

Houx JH, Garrett HE, McGraw RL (2008) Applications of black walnut husks can improve orchardgrass and red clover yields in silvopasture and alley cropping plantings. Agrofor Syst 73:181–187

Huxley P (1999) Tropical agroforestry. Blackwell, Oxford, pp 1–384

Jalilova G (2007) Effects of different types of forest management activities on diversity of birds in the walnut fruit forests in Kyrgyzstan. University of Natural Resources and Life Sciences, Vienna, pp 1–64

Jose S (2009) Agroforestry for ecosystem services and environmental benefits: an overview. Agrofor Syst 76:1–10

Juldashev U, Messerli S (2000) Trees and agriculture in the walnut fruit forests of southern Kyrgyzstan: current situation and the potential for agroforestry. Intercooperation, Bishkek, pp 1–77

Magagnotti N, Nati C, Picchi G, Spinelli R (2011) Mechanized thinning of walnut plantations established on ex-arable land. Agrofor Syst 82:77–86

Mamadjanov DK (2006) Study of varieties and diversity of walnut forms in Kyrgyzstan. Schweiz Z Forstwes 157: 499–506

Marsinko APC, Phillips DR, Cordell HK (1984) Determining residential firewood consumption. Environ Manage 8: 359–365

Martin S, Jalilova G (2000) Agroforstwirtschaft im Süden Kirgistans. Das Fallbeispiel Sart-Mazar, Arslan-Bob. Intercooperation KIRFOR, Jalal-Abad, pp 1-32

Mary F, Dupraz C, Delannoy E, Liagre F (1998) Incorporating agroforestry practices in the management of walnut plantations in Dauphine, France: an analysis of farmers' motivations. Agrofor Syst 43:243–256

Matter M (2005) Monitoring of agroforestry practices in the walnut fruit forest in southern Kyrgyzstan. Elaboration of dissemination material for the project's aims and results. ETH Zurich, Institute for Forest and Walnut Research of the National Academy of Sciences, Bishkek, pp 1–45

Messerli S (2002) Agroforestry: a way forward to the sustainable management of the Walnut Fruit Forests in Kyrgyzstan. Schweiz Z Forstwes 153:392–396

Müller U, Sorg J-P (2001) Gestion multifonctionnelle des forêts de noyer du sud du Kyrgyzstan: tradition, problèmes actuels, perspectives. Schweiz Z Forstwes 152:138–144

Nair PKR (1993) An introduction to agroforestry. Kluwer Academic Publishers, Dordrecht, pp 1–499

Nair PKR (2007) The coming of age of agroforestry. J Sci Food Agric 87:1613–1619

Newman SM (2006) Agronomic and economic aspects of walnut agroforestry in the UK. In: Malvolti D, Avazato D (eds) Proceedings Fifth International Walnut Symposium. Acta Hortic 705:65–67

Oosterbaan A, Schepers H, Kwanten E (2006) Walnut as a farm crop in The Netherlands: an agroforestry project in the east and selection of cultivars for organic cultivation in the north. In: Malvolti D, Avazato D (eds) Proceedings Fifth International Walnut Symposium. Acta Hortic 705:27–34

Pini R, Paris P, Benetti A, Guidi GV, Pisanelli A (1999) Soil physical characteristics and understory management in a walnut (*Juglans regia* L.) plantation in central Italy. Agrofor Syst 46:95–105

Pomerleau J, Lock K, McKee M (2003) Discrepancies between ecological and individual data on fruit and vegetable consumption in fifteen countries. Br J Nutr 89:827–834

Rehnus M, Sorg J-P (2010) Sustainable management of unique natural walnut-fruit forests in southern Kyrgyzstan. Tropentag 2010. ETH Zurich, Zurich. http://www.tropentag.de/2010/abstracts/full/306.pdf

Rehnus M, Sorg J-P, Pasinelli G (2011) Habitat selection and attributes of potential cavity trees of the white-winged woodpecker (*Dendrocopos leucopterus*) in the walnut-fruit forest in Kyrgyzstan. Acta Ornithol 46:83–95

Rehnus M, Nazarek A, Mamadjanov DK, Venglovsky BI, Sorg J-P (2012.) Unique walnut forests in Kyrgyzstan: High demand for firewood leads to overuse. J Forest Res

Romer B (2005) Agroforestry in Tajikistan overview of the current situation, the potential, and the influencing factors of agroforestry systems. CAMP, Dushanbe, pp 1–37

Scheuber M, Köhl M, Traub B (2000) Forstliche Inventur als Planungsgrundlage für die Forstwirtschaft Kirgistans. Schweiz Z Forstwes 151:75–79

Schmidt M (2005) Utilisation and management changes in south Kyrgystan's mountain forests. J Mt Sci 2:91–104

Schmidt K (2007) Livelihoods and forest management in transition: knowledge and strategies of local people in the walnut-fruit forests of Kyrgyzstan. University of Reading, Reading, pp 1–406

Sorg A (2007) Selected aspects of agroforestry in southern Kyrgyzstan‘s walnut fruit forests. KIFOR, ETH Zurich, Zurich, pp 1–55

Thapa B, Sinclair FL, Walker DH (1995) Incorporation of indigenous knowledge and perspectives in agroforestry development: 2. Case study on the impact of explicit representation of farmers knowledge. Agrofor Syst 30:249–261

Venglovsky BI (1998) Potentials and constraints for the development of the walnut-fruit forests of Kyrgyzstan. In: Blaser J, Carter J, Gilmour D (eds) Biodiversity and sustainable use of Kyrgyzstan's walnut-fruit forests. IUCN, Gland; Intercooperation, Berne, pp 73–76

Venglovsky BI (2006) Bioecological peculiarities of renewal and development of walnut forests in Kyrgyzstan. National Academy of Sciences, Bishkek, pp 1–170

Venglovsky BI, Mamadjanov DK, Sorg J-P, Rehnus M, Sarymsakov Z, Abdukakharov BA (2010) Bioecological bases for forest management of walnut forest in Kyrgyzstan and their multifunctional use. The Southern Branch of the Academy of Science of the Kyrgyz Republic, Bishkek, pp 1–183

Walker DH, Sinclair FL, Thapa B (1995) Incorporation of indigenous knowledge and perspectives in agroforestry development: 1. Review of methods and their application. Agrofor Syst 30:235–248

Willis RJ (2000) *Juglans* spp., Juglone and allelopathy. Allelopathy J 17:1–55