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Afforestation and Reforestation of Walnut Forests in Southern Kyrgyzstan: An Economic Perspective

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Kyrgyzstan is home to one of the largest areas of natural walnut forest in the world. These forests support significant genetic diversity of many important ancestral strains of fruit and nut tree species. The walnuts from those forests are a major source of cash income for many households in that region. Most of the walnut forests are overgrazed, which effectively hinders natural rejuvenation. This has resulted in overaged and degraded forests. Currently, tree cutting for timber is forbidden under a moratorium. In some instances, walnut trees grow in agroforestry systems together with potato and corn as annual crops or apples and berries, alongside hay. Reforestation and afforestation in the walnut forest region is imperative to secure walnut harvests and associated incomes once the existing trees start bearing fewer nuts. The objective of this study was to analyze the economic performance of a range of representative combinations of annual crops, berries, and fast-bearing fruit trees in reforestation and afforestation plots. This included hypothetical timber utilization in order to be able to bridge the income gap until newly planted walnut trees bear nuts. Data were based on semistructured household and expert interviews. In all plots there was grassy vegetation, which was harvested for hay. In some of the plots, corn and potatoes were grown as annual crops. Additionally, in part of the plots apple and berries were grown next to walnuts. The net present value of the farming systems for a 20-year period was highest for the 2 systems that included hypothetical timber utilization. Walnut and haymaking performed worst, with a negative net present value. All non-timber systems yielded an income gap until around year 10, when walnut trees begin to fruit.

Keywords: *Wild fruit forests; agroforestry; forest degradation; overgrazing; logging ban; forest recruitment; Central Asia.*

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Introduction

One of the largest areas of natural walnut forest in the world is found in mountainous southern Kyrgyzstan (Venglovskiy et al 2010), representing an important resource both locally and globally. Internationally, these forests contribute to the goals of the Convention on Biological Diversity (CBD), that is, to protect and conserve biodiversity, as they support significant genetic diversity of many important ancestral strains of fruit and nut tree species (Temirbekov 2010; Cantarello et al 2014). With the erosion of agrobiodiversity in mind, the conservation of this rich genetic treasure trove in the form of fruit and nut species is therefore of worldwide importance to global food security (Frohardt 2010; Venglovskiy et al 2010; Shanley et al 2015). Additionally, the forested land cover contributes to the regulation of water flows for downstream areas in the densely populated Ferghana Valley and helps prevent soil erosion (Temirbekov 2010; Cantarello et al 2014).

For the communities living in and near them, the forests are of crucial importance as an income source and for food security (Fisher et al 2004). The walnuts harvested from those forests are a major source of cash income for all households in that region (Schmidt 2005). Walnut yields are highly variable, with a good harvest occurring approximately every 6 years (FAO 2006). Various factors impact the walnut yield, including “late spring and early autumn frosts, low temperatures below zero in winter, high air temperatures in spring and summer, dryness of air in winter and spring” (Venglovskiy et al 2010). These factors and the trees’ hygrophilous nature suggests that climate variability and the rising prevalence of weather extremes associated with climate change could have a negative impact on walnut yields in the future (Frohardt 2010; GIZ 2014). Next to nuts, those forests supply local communities with other important non-timber forest products, such as fruits and berries (apple, almond, blackcurrant, barberry, hawthorn, dog rose, cherry plum), mushrooms, and non-edibles (eg medicinal plants, fuelwood) (FAO 2006). Most of the walnut forests are grazed. However, in the absence of a proper management system—due to broken-down institutions, economic crises, high densities of stock, and lack of grazing rotation—the result has been overgrazing in most of the forests.

Unfortunately, during the Soviet era, natural resource management was already inefficient and harmful (Ludi 2003; Orozumbekov et al 2009), resulting in extensive degradation to pastures and other natural resources, including a reduction in the walnut forest area during the second half of the 20th century until today (Fitzherbert 2000). Additionally, since Kyrgyzstan's independence from the Soviet Union in 1991 and the collapse of its industries, public services, and governmental administrations (Rehnus et al 2013), local communities in the south have become heavily dependent on these walnut forests for their multifunctional uses (Carter et al 2003; Beer et al 2008; Rehnus et al 2013).

Despite the fact that agricultural land was privatized following the breakup of the Soviet Union, forests are still state owned and managed by state forest enterprises called "Leshozes," which are in charge of different areas of the walnut forest (Carter et al 2003). Leshozes were developed during the Soviet era and were funded to provide jobs for local communities that lived and worked within these forests; they were run in a very top-down way with 10-year management plans (Carter et al 2003). The Leshozes are still operational today, and although they now have more autonomy in how to develop the 10-year plans, they are underfunded, and ownership and motivation in forest management is low (Carter et al 2003; Undeland 2012). Consequently, there is a high level of corruption in the management of these forests, including illegal logging and inconsistent management practices. In addition, the leasing system used by the Leshozes is highly variable and does not support the sustainable management of the forest (Carter et al 2003; Rehnus et al 2013). For example, tenants can lease the same area of land for single or multiple products, such as, walnuts or haymaking, which often results in plots leased by several tenants for different products (Rehnus et al 2013). Unfortunately, this can lead to disputes as each tenant cares for his or her own interests at the expense of the others; for example, haymaking can damage new trees (Carter et al 2003), grass roots can restrict regeneration and growth of trees (Balandier et al 2006), and tree canopies shade hay (Rehnus et al 2013). Livestock are also often grazed within these plots during the winter, which can compact soil and restrict growth of hay and walnut trees (Orozumbekov et al 2009); this intense and unmanaged use of plots ultimately leads to forest degradation. Also, fees for land charged by Leshozes vary considerably (personal observation gathered during interviews), with some tenants paying much higher fees than others.

Under this pressure, walnut forests have decreased by approximately 90% in the past 50 years due to overgrazing, fuelwood collection, and illegal logging, and most of the remaining forests are overaged (Beer et al 2008; Frohardt 2010). This situation makes reforestation of degraded walnut forests and afforestation in the walnut forest region imperative to secure walnut harvests and associated incomes once the existing trees bear fewer nuts. But under the current grazing pressure, fencing or other measures are crucial to enable walnut seedlings and saplings to survive and grow to fruit-bearing trees.

In the course of reforestation (areas previously covered by walnuts) and afforestation (areas that have been without tree cover for a longer period of time, eg grazing land), land users have to bridge the time until the newly planted walnut trees bear nuts and yield income. Agroforestry approaches, that is, using annual crops and trees that bear fruits faster than walnut on the reforestation or afforestation plots (Messerli 2002), may help to bridge this time and provide income until the new walnut trees bear nuts. The objective of this study was to analyze the economic performance of a range of representative combinations of annual crops, berries, and fast-growing fruit trees in reforestation and afforestation plots in order to recommend agroforestry approaches that enable land users to plant walnut without facing a long period without income.

As forest degradation is a serious problem throughout Kyrgyzstan, there is a logging ban over all forestland, especially walnut forests (Undeland 2012). Therefore, a set of crop (including hay), berry, and fruit tree combinations that are in use in the study area was investigated as income sources under conditions of afforestation, that is, planting new walnut trees on land that has not been covered by trees. Additionally, the income that could be generated from the sale of the timber of old walnut trees was calculated for 2 hypothetical plots. In this study walnut burls, which are sold for very high prices due to their rarity, were not specifically considered.

Study region

The study region was located in the walnut forest region in southwestern Kyrgyzstan, as shown in Figure 1. Within that walnut forest region, this investigation focused on the area around the village of Arslanbop (Bazarkorgon County), about 40 km north of Jalalabad City. The investigation was undertaken in August 2015.

The walnut-dominated forests are distributed at an elevation of 900 m to 2200 m, with 90% found between 1400 m and 1800 m. Any lower and there is too little rain, especially during summer, while the area above the upper boundary is too cold. Annual precipitation at Ak-Terek-Gava meteorological station (elevation 1750 m) is 1090

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FIGURE 1 Location of the walnut forest region in southwestern Kyrgyzstan (dashed red). (Map: extract from Google Maps)

mm; but annual precipitation decreases with lower elevation. Average January and July air temperatures are −3.1°C and 20.5°C, respectively. During frost periods, air temperature falls to −20°C (Venglovskiy et al 2010). At the lower forest boundary (900 m), annual precipitation is only 535 mm so that forest stands are distributed only on northern exposed slopes. Precipitation peaks in spring and autumn with about half of the annual precipitation falling in the months of March, April, May, and October. August and September are the driest months.

Walnut (*Juglans regia*) is the dominant tree in the forests. Apple is the most widely spread understory tree. Next to apples and berries, fruits like barberry, hawthorn, dog rose, and cherry plum are also part of the understory vegetation. The species composition of the herb layer is largely determined by the crown closure of the walnut trees and grazing practices.

The land in the walnut forest zone is state owned (State Forest Fund) and administered by State Forestry Enterprises (Leshozes). Forested land plots as well as grassland and agricultural field plots are leased to tenants.

Methods

For the analysis of economic performance, 12 land-use systems were chosen for being typical of the region (based on interview data). Initially, the analysis focused on the potential use of fallow plots, that is, plots used for pasture that have the potential to be afforested/reforested. The analysis included the following proposed farming systems: *walnut and hay* (WH); *walnut, hay, and apple* (WHA); *walnut, potato, and hay* (WHP); *walnut, hay, and blackcurrant* (WHB); *walnut, hay, and almond* (WHa); *walnut, hay, and corn* (WHC); *walnut, hay, and lucerne* (WHL); and an additional system called *multicropping* (MLT), that is, diverse agroforestry system comprising all of the aforementioned crops.

Using data gathered through questionnaires, average yields (kg/ha) and prices (KGS/kg) were obtained for the following crops: almond, apple, blackcurrant, corn, hay, lucerne, potatoes, walnut; costs for each farming system were also gathered this way. In 2015, 1 USD converted to approximately 64 Som (KGS). Mean values were used for all products apart from almond and apple yields, in which the reported annual variation was accounted for (explained further in a later section). Additionally, to consider those systems in drier locations without access to irrigation and reliant on rainwater, 2 extra analyses were done for *walnut and hay – dry and rainfed* (WHD) and *walnut, almond, and hay – dry and rainfed* (WHaD). To account for the differences in conditions, walnut and hay yields were reduced significantly for dry and rainfed plots. The 2 hypothetical systems in the walnut forest, that is, typically overaged stands, were the basic systems of walnut and hay production and the multicropping system. These were combined with the potential income obtained from the hypothetical harvesting (currently not permitted due to the general moratorium on timber logging) of walnut timber: *walnut, hay, and timber* (WHT) and *multicropping and timber* (MLTT).

Both quantitative and qualitative data to understand the potential income of different land-use systems were gathered through semistructured interviews with land-plot tenants and selected experts during August 2015 (Rehnus et al 2013). A total of 25 farmers were interviewed for this investigation, with 17 farmers from potential afforestation plots (ie plots without walnut trees) and 8 from already forested plots (reforestation plots). The following information was gathered by interviews:

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1. Basic information about interviewees (age, gender, livelihood strategy, and experience);
2. Crop types, yields, and total outputs; and
3. Inputs such as labor, lease, fencing, and other costs.

A field survey was conducted in August 2015 at selected plots in Arslanbob walnut forest. The plots were selected to represent the range of different farming activities typically conducted within the region, including variable tree density, crop type, and size of plot. We measured various plot attributes, such as the size of area, cropped area, and number of apple trees and walnut trees. The analysis compared activities that can be undertaken on a 1-ha plot and included the typical sized area (recorded in interviews) for certain agricultural crops (berries, potatoes, corn) found in walnut plots and their potential yield. The size of the agricultural area used was also deducted from the total haymaking area to understand the realistic income generation per hectare of individual products, for example, hay and berries. Production costs were deducted from revenues to calculate the total net benefits gained from different farming systems.

The net present value (NPV) for the 20-year period was calculated for each system (Hall et al 2000; Conservation Strategy Fund 2015). A 20-year period was chosen as this is the predicted life span of the fence (personal communication, Davilet Mamadjanov, nongovernmental organization [NGO] Lesic Yug, 29 October 2015), and the time in which returns would need to be made before possible fence renewal. The analysis was done as a farm-gate analysis so that transport costs of farm products were excluded.

The NPV is the sum of the present value (PV) of the net benefit for each year. The PV of the net benefit for each year was calculated using a discount rate of 3% (Tredinnick 2012):

$$PV = B/(1 + i)^n$$

in which B = net benefit in a given year, i = discount rate, and n = number of years. Net benefit (B) was calculated as the difference of sum of revenues and sum of costs.

Revenues in this study came from walnuts, fruits, berries, crop yields (including hay), and walnut timber (only in the hypothetical systems 11 and 12). Costs were labor and fencing costs.

Walnut trees begin to bear fruit between 6 and 10 years (average 8 years) (Venglovskiy et al 2010) and therefore income for walnut trees was not included in the analysis until year 9. Almond trees typically bear fruit 3–4 years after planting and are quite often alternate bearing trees with a large crop followed by a lighter one (Boriss and Brunke 2005; personal communication, Davilet Mamadjanov, NGO Lesic Yug, 7 August 2015). Therefore, almond income was not included in the analysis until year 4, and alternate years had a value of 50% to account for lighter almond yields. Apple trees begin to bear fruit between 2–5 years (Stark Bros 2015a) and typically have a good crop (maximum yield of 1053 kg) once every 2–3 years (FAO 2006), so the analysis began with a maximum yield value every 3 years starting at year 4, and all other years had the average value.

The agricultural crops (potatoes and corn in the study area) can be harvested in their first year, but berries will not be ready to harvest until they are between 2–3 years old (Stark Bros 2015b); thus, income for berries was entered at year 3. Agricultural crops and hay grown within the walnut forest will be less productive than on the fallow plots, described previously, due to the impacts of tree shade (Venglovskiy et al 2010). To account for this, the minimum yields recorded (during interviews) were used in the analysis. Additionally, fruiting of natural walnut stands, compared with managed stands, is typically low due to site conditions and tree quality (Venglovskiy et al 2010), and, therefore, to incorporate this difference the lowest yield recorded in interviews was used.

To account for the negative impact of walnut canopies on yields, from the time of the first walnut yield (in year 9), hay income was reduced by an estimated 5% every year within the analysis. Income from agricultural crops was reduced by 5% from year 9, but berries were not as they are relatively shade tolerant (Lawrence Fruit Tree Project 2015). As crop yields decrease, so do labor requirements, and therefore, the cost for labor was also reduced by 5% across plot analyses.

For dry plots in lower elevations of the study area, which are not irrigated (dry, rainfed) interview data from drier sites were be used, that is, 300 kg/ha for walnuts and 966 kg/ha for hay yields. Almond yields remained the same as these are typically more tolerant of drier conditions, and therefore. yields may not be as affected (Fereres et al 1981).

International timber experts gave information per cubic meter for lumber grade timber, so this was used for estimating income gained from timber sales.

Walnut tree height and diameter at breast height (DBH) helped to understand potential timber quantity available to local communities. Trees achieve their highest timber value after they reach a DBH between 25–40 cm and upward (Ontario Woodlot Association 2001); therefore, timber values to be entered were based on trees cut with a DBH of 40 cm. Based on information provided by a forestry expert (personal communication, James Brushwood, arboricultural contractor, 10 November 2015) labor requirements to fell 2 trees with a DBH of 40 cm and a height of 7 m will be approximately 10 days of labor. The forestry commission (2015) estimated that from a tree with a DBH of 40 cm and a height of 6–10 m, 4–7 trees would generate 5 m^3 of timber. The mean number of trees recorded in the natural walnut stands was 59 trees; thus, 2 trees equates to approximately 3% of the total tree cover and would therefore have minimal impact on overall

TABLE 1 Description of the plots from which interview data were collected.

Name of plot	Area	Trees and crops
Afforestation plots		
Kyzyl Unkur	5.00 ha	1200 walnut saplings, mature apple
Kok Alma	5.00 ha	Walnut and almond saplings, hawthorn (*Crataegus monogyna*), barberry (*Berberis* spp.), hazelnut (*Corylus avellana*)
Achi	5.00 ha	Walnut saplings, *Crataegus monogyna,* hackberry (*Celtis* spp.)
Arslanbop-GIZ	5.00 ha	Walnut, apple, lucerne (*Medicago sativa*)
Jay Terek A	3.00 ha	2560 walnut seedlings, corn, potato
Jay Terek B	2.00 ha	600 walnut saplings, potato, hay (grass)
Gava Unkur	5.00 ha	1000 walnut saplings, lucerne
Reforestation plots		
Arslanbop-1	2.67 ha	37 walnut trees, 210 apple trees, few cherry plum, dog rose, hawthorn shrubs, 1918 m^2 potato, 532 m^2 lucerne
Arslanbop-2	3.38 ha	65 walnut trees, 139 apple trees, few cherry plum trees, 3021 m^2 lucerne hay, berries
Arslanbop-3	1.31 ha	52 walnut trees, 176 apple trees, few cherry plum and dog rose trees, 1971 m^2 potato
Arslanbop-4	0.31 ha	11 walnut trees, 1 apple tree, 1 cherry plum
Arslanbop-5	0.27 ha	52 (mostly young) walnut trees, 10 apple trees
Arslanbop-6	1.74 ha	113 walnuts trees, 93 apple trees, few dog rose, hawthorn and cherry plum trees
Arslanbop-7	1.90 ha	91 walnut trees, 185 apple trees, 2495 m^2 potato
Arslanbop-8	1.96 ha	58 walnut trees, 78 apple trees, few dog rose trees, 4025 m^2 potato, 525 m^2 corn

forest cover. The calculations are made under the assumption that trees will be replanted to ensure future sustainability, and therefore, costs for planting were also factored into the analysis.

Labor costs were based on the average of 500 KGS per person per day (personal communication, Ibrahim Karimijanov, farmer, 21 August 2015) except where specialist roles are required. The mean fencing costs per hectare were entered in the first year and for 5 years in total, as this was the repayment deadline. Maintenance costs for fencing and irrigation pumps were estimated based on local knowledge (personal communication, Davilet Mamadjanov, NGO Lesic Yug, 10 November 2015) and added from year 3.

Results

The farming plots that were covered by interviews are described in Table 1. In all plots there is grassy vegetation, which is harvested for hay. In half of the investigated plots, corn and/or potatoes were grown as annual crops. The major agricultural products, including annual crops, fruits, and walnuts, are listed in Table 2 with their yields and selling prices. Table 3 shows the particular yields by farming system. The detailed costs for the inputs are given in Table 4.

Next to the products listed in Table 2, the following products were grown on part of the plots or collected from the forests but were not traded: barberry, hawthorn, dog rose, wild apple, cherry plum, plum, tomatoes, cabbage, cucumber, and medicinal plants.

The NPV of the farming systems for a 20-year period was highest for the 2 systems that included hypothetical timber utilization, that is, walnut, hay, and timber and multicropping and timber (Figure 2). Walnut and hay performed worst with a negative NPV.

Figure 3 shows the trajectory of income from each farming system, including the year in which the system began to provide income to tenants. Income generation was highest when timber was harvested within a plot. Multicropping combined with timber harvest (MLTT) provided more benefits than the combination of walnut, hay, and timber (WHT). MLTT begins with high income from timber sales, but the high labor costs for agricultural production, fence repayments, and maintenance causes income to decrease until debts are paid off and berry income increases revenue. The walnut, hay, and timber (WHT) plots also decrease for the first few years, as fencing repayments and maintenance costs are higher

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TABLE 2 Mean values and range of yields (kg/ha) and selling prices (KGS/kg) for different agricultural products. (1 USD = 64 KGS).

Product	Mean yield (kg/ha)	Range of yield (kg/ha)	Mean selling price (KGS/kg)	Range of selling price (KGS/kg)
Almond	100	100–100	100	100–100
Apple	431	153–1053	15	2–50
Black currant	2083	1667–2500	33	44–56
Corn	16,823	5074–28,571	18	10–22.5
Hay	2241	324–6667	4	1.8–5.9
Lucerne	1626	728–2800	5	4.4–6.6
Poplar	–	–	10,000[a)]	–
Potato	14,455	2469–20,855	13	5–25
Walnut	446	51–1000	73	50–300

[a)] Income expected for a 15-year old tree.

than potential income generation of the plot; however, once debts are paid off, revenue increases steadily over the 20-year period. Timber sales enable positive income generation from the first year of these plots.

All non-timber systems yield negative values until later in the forecast, around year 10, when walnut trees begin to fruit; this is due to the initial fence payment (crucial to protect trees from grazing animals). Walnut, hay, and apple (WHA) and walnut, hay, and almonds (WHa) yielded the highest benefits of all non-timber plots, but income remained negative until year 10 due to the high costs of fence, maintenance, and irrigation. It is not until walnut begins to bear fruit that plots make up for this initial investment. However, these systems surpass the other systems due to the lower production costs of trees, which need fewer inputs.

Walnut, hay, and berry (WHB) plots also do not generate positive values until after year 10, when walnut income begins to make up for the high initial investment in the fence and higher labor costs. Plots with walnut, hay, and lucerne (WHL) and only walnut and hay (WH), respectively, are next in terms of potential benefits. However, their NPV is significantly lower than that of the WHB, WHA, and WHa plots, and they also do not generate a positive income until year 10 due to fencing, irrigation, maintenance costs as well as the low income

TABLE 3 Yields of walnuts, hay, and other crops by particular farming system (kg/ha).

Farming system	Crop yield kg/ha							
	Walnut	Hay	Lucerne	Corn	Berries	Apple	Almond	Potato
Walnut and hay	446	2241						
Walnut, lucerne, and hay	446	2129	81					
Walnut, apple, and hay	446	2241				431		
Walnut, corn, and hay	446	2039		1514				
Walnut, potato, and hay	446	1927						2026
Walnut, berries, and hay	446	2151			83			
Walnut, almond, and hay	446	2241					100	
Multicropping (agroforestry)	446	1255		1514	83	431		2026
Timber, walnut, and hay	300	324						
Timber and multicropping	300	324		457	83	153		348
Walnut and hay (rainfed)	300	966						
Walnut, almond, and hay (rainfed)	300	966					100	

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TABLE 4 Annual costs for the different inputs for the investigated farming systems (KGS). Labor costs based on typical daily rate of area; labor needs based on interview data (I USD = 64 KGS).

Input	Cost (KGS/ha/y)
Tree harvest labor	12,500
Walnut Leshozes fee	1552
Hay harvest labor	3072
Fee to the Forestry Administration for hay making	620
Potato labor fee	21,504
Rent to the Forestry Administration for potato cropland	225
Potato other fees (fertilizer)	6720
Berry labor	1000
Corn labor	21,504
Rent to the Forestry Administration for corn cropland	225
Corn other fees (fertilizer)	4320
Costs [KGS/ha]	
Poplar felling[a)]	500
Walnut timber harvest[b)]	17,600
Irrigation (pump/labor)[c)]	16,859
Pump maintenance[d)]	1102
Fence repayments[e)]	8981
Fence maintenance[f)]	1028

[a)] Year 15; only once.
[b)] Timber harvest costs include felling, logging, skidding, loading, replanting. Year 1; only once
[c)] Year 1; only once.
[d)] Starting year 3.
[e)] First 5 years only.
[f)] Starting year 3.

potential of hay and lucerne. Multicropping (MLT) does not generate positive benefits until year 13, which is when walnut yields begin to balance the high costs of the initial investment and high labor costs of crop production. Potato and corn production have high labor costs in relation to the potential income generated by their sale but are important for subsistence needs. Maintenance costs also affect the potential income of the plot.

Walnut, hay, and corn (WHC) plots begin to generate a positive value at year 10 but with significantly lower NPV. The NPV of this plot is very similar to that of walnut and hay combined with potato (WHP). However, the latter plot does not begin to generate a positive NPV until year 13. Walnut, hay, and almond (WHa) plots are the lowest yielding of all viable plots and do not generate positive values until year 14. Almonds bear fruit very early, and the yield and price of these nuts are relatively high with much lower production costs than other agricultural crops, so even in dry conditions this system can generate positive income once walnut trees fruit. Finally, the walnut and hay (dry and rainfed) (WHD) plot is the least productive, which could be attributed to the low yields of walnut and hay in drier conditions combined with high initial costs for fencing and ongoing maintenance.

Discussion

Traditionally, besides livestock production, haymaking and walnut harvesting are the main sources of income in these walnut forests (Rehnus et al 2013). This investigation has shown that the economic performance of haymaking surpasses that of agricultural crops due to lower inputs, that is, labor costs. However, both lucerne and hay plots generated less than the plots comprising tree or berry products, which sell for a higher value and have fewer costs. Farmers typically do not sell hay; they use it for their livestock, which gives hay significantly more value than its actual selling price. Livestock contributes to both income and food security: during bad harvests, livestock is a good buffer to overcome times of economic difficulty.

Furthermore, it is common for farmers to use the corn they grow to feed their livestock, giving corn, and the farm systems that grow corn, a higher value than the market value. This highlights a key synergy between crop production and livestock rearing for income and food security, demonstrating the importance of both livelihood strategies for poverty reduction. However, it is important to note that although corn has economic and social value via fodder and food, its production often erodes the soil in which it is grown. It is therefore not sustainable in the long term without significant crop rotation (Falk 2013), which is not always possible within small farming plots that are used for subsistence only. This suggests that there are trade-offs between accepting the negative impact of corn production (and thus reducing the ability of the land to grow significant yields into the future) and opting for other crop systems.

The results from the analysis show that afforestation plots, which include hay and tree crops only, such as apple and almond, reaped significant economic benefits. This is partly due to the notable differences in inputs required compared with other farming systems (Wilson 2009), that is, less labor needed and no fertilizers or pesticides required. Potato, corn, and multicropping systems, which have higher labor requirements, do not generate benefits as high as those of plots based on tree crops and come with other disadvantages, such as ecological damage, including soil degradation, which could be avoided by intercropping where farm plot size allows it. Furthermore, the berry plot, due to its lower labor requirements combined with higher sale price, resulted in one of the highest NPVs after the tree cropping systems. Due to the

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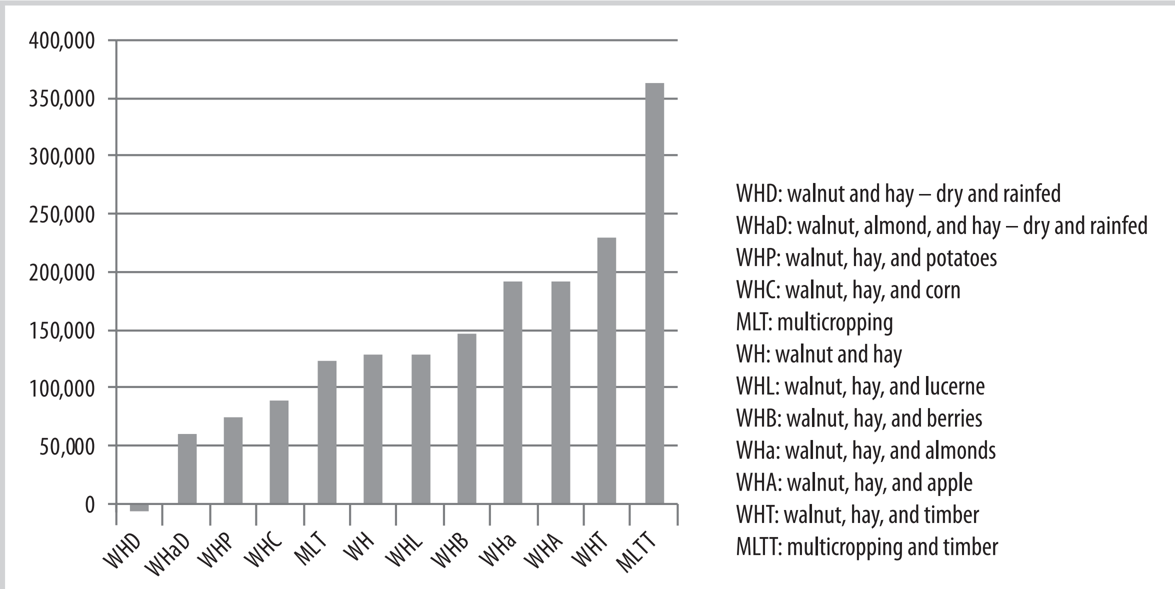
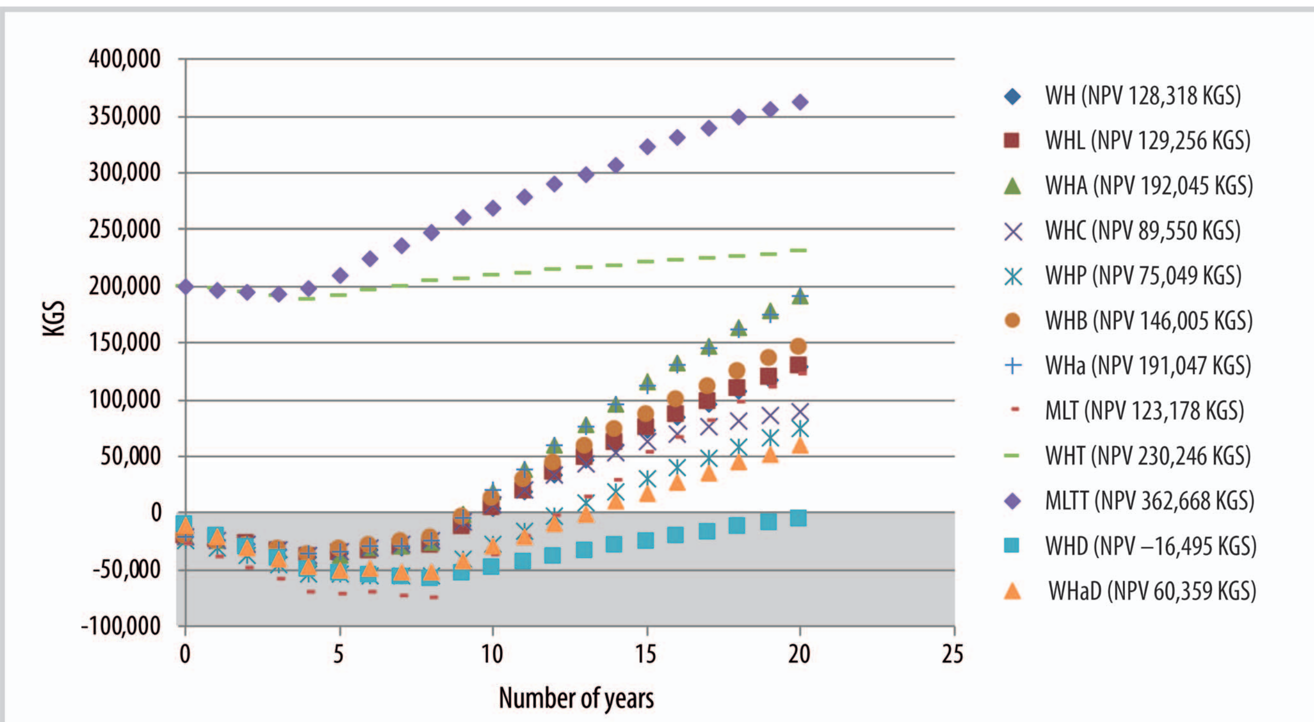
FIGURE 2 The net present value of farming systems for a 20-year forecast.



initial fencing costs, most plots do not generate income until walnut trees yield nuts, making farming for subsistence imperative until the trees begin to yield. Walnut crops in all production systems contribute significantly to income generation, providing the most benefits compared with all other products and requiring less labor, highlighting the importance of walnut crops and current afforestation efforts. Due to their high market value (FAO 2006), walnut trees can help to significantly reduce poverty, although the full reward will not typically be felt for 20 years, benefiting the farmers' children and grandchildren.

FIGURE 3 Accumulated income and payback potential forecast for 20 years into the future with net present values.



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Timber sales completely bridge the gap between tree planting and fruit bearing, while buffering negative yields due to weather conditions and low yields. The current moratorium is counterproductive to sustainable forest management, and forest improvement measures, such as felling, can actually promote the natural regeneration of walnut trees that do not thrive in the present low light conditions of forests (Slusher et al 1993; Venglovskiy et al 2010; Cantarello et al 2014). Moreover, thinning of walnut stands can improve conditions for other subsistence crops and improve nut yields by allowing a fuller development of crowns when suitable (Slusher et al 1993).

The walnut trees in the study area are becoming overaged (Venglovskiy et al 2010), which can result in tree defects that can reduce the potential timber value (Slusher et al 1993). Therefore, the state would need to act now if it hopes to gain any benefits from their current stock of walnut trees and achieve the forest growth needed for long-term benefits. By placing additional value on tree resources, local and national stakeholders, the forest and pasture users, may encourage the afforestation, and subsequent protection, of their forests. Timber sales can be managed sustainably and can help develop a mixed-age stand; sustainably managed forests can actually increase in extent even as wood is harvested (AHEC 2015). If managed in an environmentally friendly, socially just, and sustainable manner these timber products can be sold under a certification scheme, which can increase their economic value and appeal. This can potentially minimize the impact of the huge expanse of walnut forests known to have been planted in China (Zhang et al 2015) that may well be sold as timber in the future; the same certification potential applies to the nuts of these trees, too. This highlights the range of benefits sustainable timber harvesting of this valuable walnut wood can provide to local communities.

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