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ORIGINAL ARTICLE

Measurement and evaluation of timber yields and corresponding non-timber forest products of selected tree species

An exploratory study on Poplar, Acacia, Ulmus and Juglans tree species in Kyrgyzstan

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Abstract

With issues of high timber demand and illegal logging in the forest zones of Kyrgyzstan, agroforestry may serve as a viable option for rectification. Yields of timber and expected income from the most popular tree species are in most cases lacking.

The goal of this study is to evaluate the timber yields and non-timber forest product from Ulmus, Poplar, Acacia and Juglans tree species in Kyrgyzstan. More focus was allocated to Poplar as this is one of the most common and preferred tree species in Kyrgyzstan.

A sample size of 420 trees was recorded from 18 stands with 20 trees measured in each stand with the exception of Juglans which were 6 stands with 9-17 trees each

The study estimated (i) tree volume using allometric parameters (ii) age-biomass relationship (iii) Factual Branch Analysis model to estimate the above ground biomass of the different tree segments (iii) revenue deduction and NPV of Poplar trees and (iv) biological rotation Age to determine the suitable age for Poplar harvesting.

The findings show that NPV is highest at 10 years for Poplar when it is being considered for fast-growing timber. The biological rotation age was, however, higher at around 17 years. Site-specific age-biomass model appears to be suitable for estimating tree biomass since the tree allometry was found to differ significantly between studied stands even with similar age ranges. The developed relationship and tree database can adequately be applied to estimate tree volume and biomass in similar site conditions in the studied region.

Keywords: biomass , volume, net present value, growth yield, rotation age

1. Introduction

Background to the study

Kyrgyzstan is a landlocked and mountainous country in Central Asia, bordered by Kazakhstan to the north, Uzbekistan to the west and southwest, Tajikistan to the southwest and China to the east (World Factbook, 2010).

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The territory of the Kyrgyz Republic is 19.99 million ha (4.3% are forests, 4.4% - water surface, 54.0% - agricultural lands and 37.3% - other lands). Almost 95% of the territory is mountainous at more than 1500 m above sea level (asl). The average elevation is 2,750 m asl with the highest point at 7,439 m and the lowest one at 401 m. Fifty-eight percent (58%) of all human settlements in the country are located within the elevation of 1,000-2,000 m (35% of the total population) while 5% live above 2,000 m asl (Maydell, 1983).

It is estimated that the current forest cover is somewhere in the order of four percent of the total territory of the country or between 700,000 and 800,000 ha in absolute terms. Kyrgyz forests, which are all state-owned, are very limited in area, but highly diverse. They can be grouped into four main types:

- Spruce forests
- Walnut-fruit forests
- Juniper forests
- Riverside forests

Apart from natural forests of the above types, there are also plantations, chiefly of two kinds. Firstly, plantations of naturally occurring as well as introduced tree species within the area of natural distribution of the four described forest types, and secondly, plantations of Poplar near or within settled areas, for the purpose of timber production for construction and as windbreaks (Müller and Venglovsky 1998; Venglovsky 1998; Cornet and Rajapbaev 2004).

The annual demand for timber resources in Kyrgyzstan is 160, 000m3. However, timber delivered by the state forest fund in Kyrgyzstan is 30,000 to 45,000m3per year. Pressure exists on the state forests in Kyrgyzstan as the demand for timber outweighs supply almost four times. Forest lands are controlled by the state through the State Forestry Agency of Environment and Forest, which is responsible for the protection and management of the areas under their control (Orozumbekov, 2010).

Logging in the state forest fund is banned, but illegal logging still pertains. There is a gap in timber supply, which results in a vital need for timber supplement. As a way of bridging this demand, timber is imported from Russia. Nevertheless, one is more likely to have more benefits from a farmland incorporated with trees outside the state forest fund.

Since the people of Kyrgyzstan would like to maximize the potential of their land, agroforestry is a prospect for improving their livelihood. Certain practices of agroforestry are already being performed by Kyrgyz farmers (Dzhakybekova and Weyerhaeuser 2014). Timber, fodder and fruit are important for farmers and land users in Kyrgyzstan and it is imperative to know what to expect when a tree is being planted and incorporated into an agroforestry system. Agroforestry fulfils and timber demand and reduces dependency on the state forest. Agroforestry may, therefore, serve as a viable option by directly reducing the deforestation and logging rate of the natural forest by making fuelwood and timber available on nearby farmland.

To assess the potential of agroforestry in Kyrgyzstan, four tree species were analyzed during this research. These include Poplar, Ulmus, Acacia and Juglans tree species. The criteria for the selection of these tree species include:

1. The most common trees in Kyrgyzstan
2. Most preferred trees for timber among the local people
3. Durability for since this is the main source of energy for local people in Kyrgyzstan
4. Capacity for speedy aboveground biomass.

This study intends to determine the tree growth yield through an analysis which takes into account, allometric relationships. As a complementary measure to increase acceptability for the local farmers, this study finds it important to further determine the revenue from the growth yields and also to know the point where the tree can be harvested from maximum financial profit.

2. Methodology

Site Selection

The study sites for this project were within three ecological zones in Kyrgyzstan. Juglans trees were studied in Ferghana Valley, Poplar tree species were studied in Issyk Kul and Chui zones while Acacia and Ulmus tree species were also studied in Chui zone.

Study site for this research was selected on the basis of:

1. Availability of tree species on sites
2. Diversity of different elevations and age varieties for a representative conclusion.

Poplar trees were selected from 18 sites, Juglans trees from 6 sites, while Acacia and Ulmus were from one site each.

Description of Ecological Study Zones (Fig. 1)

Fig. 1 Map of study area (Source: Google Maps).

Sampling Design

A total of 420 tree data were recorded. Out of this, 300 were Populous trees, which were 20 trees selected out of different population sizes and out of 18 different stands. 20 trees were selected for Ulmus from one stand. This was also similar to the Acacia trees as 20 trees were selected from 1 stand. The total number of Juglans trees selected were 78 trees which were 15-17 trees from six stands.

The sampling methods used include systematic sampling resulting in the trees being selected randomly to omit any kind of bias. The second method which was used, although less frequently, was the opportunity sampling, where trees were selected based on availability within the suitable sites.

Sample Collection and Analysis

Fieldworks such as measurement and collection of tree parameters were conducted between July and December 2016. Data collections were performed under direct supervision and assistance from ICRAF, Bishkek, Kyrgyzstan officials.

Assessable tree parameters such as diameter, height and tree cores were taken (Fig. 2). A tape measure was used to measure the diameter (at breast height and branching) of the trees while a Nikon Forestry 550 laser rangefinder was used to measure the height of the trees (Fig. 2).

Tree cores were taken at the breast height with a 5 mm and a 2.5mm increment borer. Cores were taken once through the whole tree either north-south or east-west. The tree cores taken varied from tree stands. However, the tree cores taken exceeded more than 50percent of the stand giving a high representative pattern. The extracted cores were placed into a small cylindrical structure made of paper and were labelled, and kept into plastic bags. Thereafter, it was put into the plastic box with a due consideration for its safety.

The tree rings were measured using dendrochronological techniques to assess the tree age. The increment cores were then air dried and sanded with a sandpaper. The procedure continued until tree ring boundaries were clearly visible visually and with a microscope. All collected data in the field were analyzed mainly through computer programme using Excel. The tree age was estimated as one annual ring equal to one year.

Fig. 2 Extraction of tree cores; taking of FBA Input Parameters; measuring of tree height.

Estimation of stem biomass

Volume

The volume of all the 420 trees was analyzed taking into account tree parameters including DBH and height deduced from a formula by Waldwirtschaftsplan, (2000).

For volume analysis, different form factors were used for all these different tree varieties (Tab. 1). The form factor used in this analysis was taken from literature review considering same tree species with similar site conditions.

Tab. 1 Form Factor Used For Volume Calculation.

Tree Variety	Form Factor	
	Literature	Value
Juglans	Folliot (1960)	0.42
Poplar	Fieldwork	0.46
Acacia	Pedley (1998)	0.42
Ulmus	Semu (2001)	0.50

Calculation of Volume
V= (DBH^2 (in m)/4)*π*h (in m)* form factor
Where:
DBH= Diameter at Breast Height
π= PI
h=Height

Biomass

Biomass was also calculated for all the 417 trees with formulae that take into account tree density and volume (Zhou and Hemstrom, 2010). Previous calculations were used to develop the volume and density of the trees. The density of the species was determined through literature for same species with similar site conditions (Tab. 2).

Tab. 2 Densities used for Biomass Calculation.

Tree Variety	Density	
	Literature	**Value (kg per cubic metre)**
Juglans	FAO (2011)	660
Poplar	Suman (2016)	360
Acacia	FAO (2011)	560
Ulmus	Aussie (2007)	760

WB = (TSV × WD)
Where,
TSV = tree stem volume from ground to tip (cubic meter)
WD = wood density (kilogram/cubic meter)
WB = stem wood biomass (kilogram).

FBA Analysis

Factual Branch Analysis model (FBA), is a non-destructive measurement model, developed by ICRAF to determine below ground (root) and above ground (shoot) biomass.

In this study, the focus is only on the above-ground biomass. 17 Poplar trees from one stand were measured using the FBA method. This was estimated by measuring the stem diameter and the branch diameter at different heights of the tree. This was later inputted into the FBA model to generate the biomass of the trees including wood weight, branch weight and twig weight.

A destructive method was however used on 18 Poplar trees to determine the form factor, density and biomass of the trees. Wood samples were taken from 18 Poplar trees to determine the density (Fig. 3).

Fig. 3 Taking of FBA input data.

Analysis of Variance

A one-way analysis of variance (ANOVA) was conducted to determine the significance between the means of the different regions and elevations and its relation to diameter increment. The three different ecological regions from which the tree samples were taken were coded from 1-3 with their corresponding average diameter increment and used as the different variables during the ANOVA analysis.

The lowest elevation was 546 and the highest elevation recorded was 2353. A coding was formed with a 200 meter interval range which resulted in deriving 10 codes for the variables and corresponding diameter increment for analysis.

Age-Biomass Relationship

As a way of understanding the age-biomass relationship for the tree species, a regression procedure for allometric relationships was developed. Using Microsoft Excel and scatter plot, a graph was drawn and a suitable trendline and R-squared value was taken with age being the predictor/independent variable(x) and biomass and volume being the response/dependent variable (Y)

Residuals of the different models were plotted and compared to a normal distribution in order to determine the goodness-of-fit.

Net Present Value (NPV)

As a means of increasing acceptability of the incorporation of trees into farmlands for timber value, it is imperative to determine the financial gain of timber in Kyrgyzstan. An NPV was calculated to deduce this information. As the ages for the trees have already been deduced, other factors including the Current Market Value (CMV), discount rate and site index were calculated from available data to help establish the NPV.

NPV-Poplar

Focus was given to Poplar tree species during the calculation of the NPV as this is the most common timber species in Kyrgyzstan. Risk factors such as floods, droughts and insects were excluded in the calculation as done by Rahman et al. (2008).

The NPV determines the present value of net benefits by discounting the streams of benefits and costs back to the beginning of the base year (Rasul and Thapa 2006). The NPV is calculated by the following formula (Boardman et al., 2006).

$$NPV = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t}$$

Where,

Bt: Benefits of production by a cultivation practice

Ct: Costs of production by a cultivation practice

t : Time period /year r: Discount rate

The discount rate was adopted from The World Bank (2017). According to The World Bank (2017), the real interest rate in Kyrgyzstan varies between 2.3% to 21.5% between last ten years (2006-2016) (Tab. 3). The average real interest rate between 2007-2016 was 13.23, which was used as a discount rate to estimate the NPV in this study.

Tab. 3 Real Interest Rate of KGZ (2015-2006) (Source: The World Bank, 2016).

Year	Real Interest rate (%)
2016	19.3
2015	20.1
2014	12.9
2013	18
2012	14
2011	2.3
2010	11.9
2009	21.5
2008	2.8
2007	9.5
Avg:	**13.23**

Biological Rotation Age (BRA)

While encouraging the growth of trees for timber value, it is important to know the stage at which the tree is mature enough and profit is at its maximum. The average diameter increments have already been determined for 18 Poplar trees that were cut down, by measuring the width of wood in four quadrants and determining the average over the total life period of the tree.

Mean annual increments (MAI) which is the average growth per year the trees have exhibited to a specified age have been determined. This was determined by dividing the DBH of the trees by their current age (Husch, 1982).

The maximum MAI will be considered as the point for the BRA and this will be the age in which a stand or tree should be harvested to maximize long-term yield.

3. RESULTS

Estimation of Biomass

The biomass of all 417 trees was calculated for the different ecological zones. In order to further understand the Age-Biomass relationship for the different tree species, an age-biomass table and age-biomass relationship deduction was constructed to develop information material for the tree species on expected yield within a life cycle (Tab. 4).

The Table below presents an example of some of the different parameters that were deduced for all 417 trees to further understand the allometric relationship.

Tab. 4 Parameters deduced for all the 417 trees.

Tree Code	Tree Species	Site Name	Agro Zone	Age	Height (m)	DBH (cm)	Volume (m^3)	Mean Annual Increment (inches/year)	Biomass (kg)
10001	Acacia	Sokuluk	Chui I	14	9.2	18.4	0.110	1.314	83.69
10036	Ulmus	Sokuluk	Chui I	18	10.2	22.1	0.196	1.228	109.57
18013	Poplar	Karakol	Issyk Kul	47	29	89	8.300	1.894	2988.02
28009	Juglans	Kok-Alma	Ferghana Valley	146	10	57.3	1.083	0.392	714.91

Age and Biomass Table

An age-Biomass table was constructed for an easy derivation of the direct age-biomass relationship and also as an information material. It should be noted that the age-biomass relationship was not deduced for all 417 trees. This is because dendrological operations were not conducted on all trees for extraction of tree age (Tab. 5; Fig. 4).

Tab. 5 Age and Biomass (Acacia).

Site	No. of Trees	Age	Average Biomass
Sokuluk	1	0-5	3.47
	9	6-10	10.14
	3	11-15	45.37
	6	16-20	66.54
	2	21-25	115.75

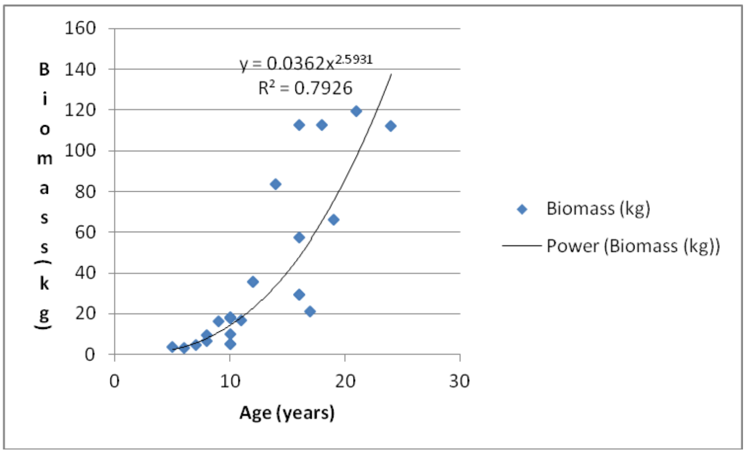

Fig. 4 Age-Biomass Relationship (Acacia).

There was a vivid relationship between the age and biomass increment in the examined Acacia data where an increase in age corresponded with an increase in biomass. The relationship is best explained by the equation $0.0362x^{2.5931}$ and the power relation $R^2=0.7926$.

The Ulmus trees recorded, although also following a trend of increasing ages corresponding to increasing biomass displayed a more unpredictable pattern in the age-biomass relationship (Tab. 6). An exponential trendline is most suitable as the data values displayed a high rise and fall at increasingly higher rates. A weaker R-squared value of 0.30 was most fitting.

Tab. 6 Age and Stem Biomass (Ulmus).

Site	No of Trees	Age	Average Biomass
Sokuluk	3	6-10	16.35
	3	11-15	29.13
	6	16-20	45.72
	5	21-25	41.69
	1	26-30	55.72

The Poplar trees were the highest recorded number of trees for this analysis and displayed the most variability in the age-biomass relationship. In order to further understand this relationship, an additional clarification is needed on how the biomass is influenced by different sites and management practices as site variability has an influence on the accumulation of biomass (Tab. 7). Karakol and Tup (Lakeside) recorded the highest biomass accumulation comparable to age. With time being a limiting factor, this study could not deduce the site and management practices which might be key in further understanding the age-biomass relationship for the different sites.

The data of Poplar was recorded on a high range of elevation and this analysis also sought to determine, through an ANOVA Analysis on Elevation, how different elevations play a role in the accumulation of biomass.

Tab. 7 Age and Stem Biomass (Poplar).

Site	County	No of Trees	Age	Average Biomass
11	Sarban Village	8	11-15	55.48
		6	16-20	45.72
		5	21-25	92.16
12	Chong-Oruktu(Lakeside)	20	50-55	648.15
13	Chong-Oruktu(Village)	1	16-20	28.75
		1	30-35	93.82
		1	36-40	68.53
		17	46-50	498.32
14	Chong-Oruktu (Mountain)	1	5-10	6.65
		1	11-15	25.13
		1	16-20	21.31
		1	26-30	62.5
		1	36-40	97.46
15	Chong-Oruktu (Lakeside)	5	10-15	117.87
		4	20-25	56.95
		3	26-30	65.94
17	Karakol(Gorge)	1	10-15	16
		3	20-25	167.9
		1	30-35	124
		1	40-45	308
18	Karakol(Town Outskirts)	1	30-35	121
		2	40-45	358.08
20	Tup Mountains	2	9-10	5.94
		3	11-15	11.19
		1	16-20	23.82
21	Tup(Upper Town)	1	6-10	0.8
		3	11-15	40
22	Tup(Town)	1	16-20	100
23	Tup(Inbetween River)	2	10-15	11.53
		4	16-20	51.2
		1	26-30	69.82
		1	36-40	175
24	Tup(Lakeside)	10	24-29	238.83
		10	40-45	650.54
26	Karakol(Lakeside	3	20-25	188
		1	26-30	148.72
		5	30-35	255.85

The Juglans trees recorded were among the oldest set of trees in this study with 40% of the data above 100 years and 1 tree well above 200 (Tab. 8; Fig. 5). This resulted in very high biomass data but also recorded a lower trend in mean annual increment. The analysis revealed that beyond the age of 70, there was a decrease in the mean annual increment of the trees even though biomass continued to increase. This conforms to about mean annual increments decreasing with age after middle years. This shows the need to know the Biological Rotation Age to determine the optimal age for timber harvest for maximum financial gain. A polynomial trendline was most suitable with Rsquared value of 0.62.

Tab. 8 Age and Stem Biomass Table (Juglans).

Site	County	No of Trees	Age	Average Biomass	Mean Annual Increment
27	Kyzyl –Unkur	1	80-100	1015.02	0.68
		1	121-140	837.05	0.40
28	Kol-Alma	2	41-60	722.02	0.81
		2	61-80	424.51	0.55
		1	141-160	714.9	0.39
29	Arstanbap-Ata	2	60-80	1760.81	0.93
		4	80-100	2837.56	0.81
		4	101-120	2683.99	0.64
		1	121-140	1757.69	0.47
		3	141-160	2432.04	0.46
30	Jay-Terek	1	101-120	1612.41	0.55
		2	121-140	3280.48	0.67
		1	141-260	2304.57	0.35
31	Archy	1	41-60	784.19	0.92
		2	61-80	1988.24	0.87
		4	81-100	1194.64	0.61
		1	121-140	2013.67	0.54
32	Kaba	1	21-40	870.96	1.51
		1	41-60	377.3	0.81
		4	61-80	1124.05	0.71
		2	101-120	937.63	0.50
		1	141-160	3317.32	0.61

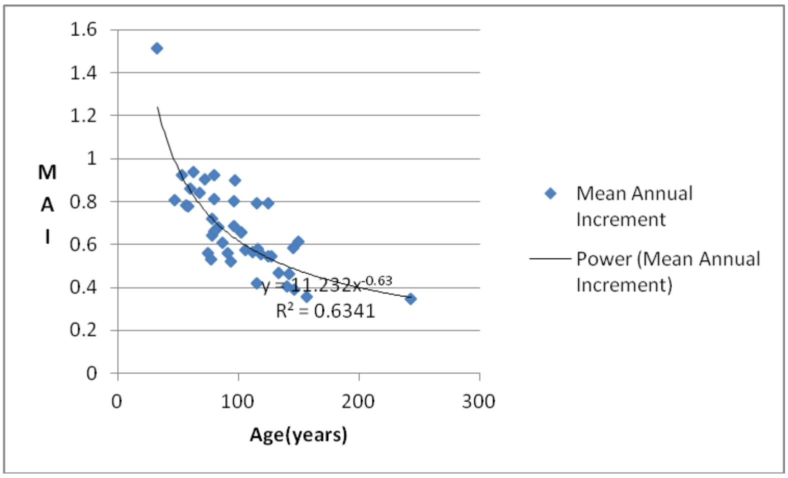

Fig. 5 Relationship Between Age and MAI(Juglans).

FBA Analysis (Poplar)

The following table presents the results of biomass from 17 Poplar trees with an FBA Analysis. A non- destructive method of Using FBA predicted the weights of the various tree segments which would otherwise only be recorded by destructively cutting down the tree.

DBH had a direct relation to the total weight recorded as increasing diameter were resulting in increasing weights of segments. The branching also played a prominent role in the final weight of the segmented tree weights.

The branch weight and wood weight are particularly interesting for this project. The branch weight is interesting for firewood as this is a huge requirement for locals in Kyrgyzstan and predictability of the branch weight is essential prior to harvest. The wood weight is also interesting for timber and wood needs. The leaf weight is considered under this analysis since it may be interesting for some locals as forage for their livestock.

The price for wood in Kyrgyzstan is either based on the age of the tree with preferably with a stem above 20cm or purchased at the market per cubic metre. The market price includes price derivation from the weight of cubic metre as 1 cubic metre is between 3000-3,500 Som (Personal information, local farmers). A conversion was made into cubic metre and Som to determine the revenue from the wood biomass acquired from the FBA Analysis (Tab. 9).

Tab. 9 FBA and Generated Revenue.

Tree No	DBH (cm)	Leaf Weight(kg)	Branch Weight (kg)	Wood Weight (kg)	Wood-Cubic metre	Cubic metre - Som
11001	18.3	4.311	183.291	246.735	0.81	2434.86
11003	19.2	17.159	4.868	97.706	0.32	964.2
11004	12.2	36.84	15.003	27.956	0.09	275.88
11005	5.9	0.595	0.705	4.212	0.01	41.57
11007	19	5.749	1.056	268.894	0.89	2653.56
11008	28.1	25.85	9.066	312.373	1.03	3082.63
11009	6.7	0.341	0.366	2.208	0.01	21.79
11010	19	2.275	0.578	379.159	1.25	3741.7
11011	20	14.565	6.341	148.195	0.49	1462.45
11012	13.3	1.145014	0.343947	52.8575	0.17	521.62
11013	16.4	4.76319	5.177316	80.23255	0.26	791.77
11015	18.8	2.073548	1.302084	437.5552	1.44	4317.98
11016	11.7	107.1671	109.9246	33.31526	0.11	328.77
11017	13	3.956436	3.391365	39.72478	0.13	392.02

Net Present Value (Poplar)

Assuming a perimeter of 1ha (100m*100m) land, i.e. 400 m, a total of 992 trees can be planted in one rotation period. Input data on cost and current market value on Poplar was generated from word of mouth of Kyrgyzstan farmers. It was found that the cost involved in Poplar production is minimal. Trees are directly sold to local contractors on the field after ten years of the plantation, which didn’t incur any harvesting costs (Tab. 10; Tab. 11).

In order to realistically generate the NPV, the highest cost for planting and the lowest current market value was chosen. It should, however, be noted that the cost for Poplar cultivation in Kyrgyzstan is minimal (Tab. 12).

Tab. 10 Cost for growing Poplar.

Activities	Purpose	Unit	Times	Unit Cost(Som)	Total Cost (Som)
Sapling	Planting	Ha	1	5-20	5-20
Pruning		Ha	2	10	20
Total					25-40

Tab. 11 Revenue from Poplar.

Prod. Per hectare	CMV per Tree (Som) after..		Per Unit Price(1m3) Som	Revenue (per hectare after..)	
	5 years	10 years		5 years	10 years
992	500	1000	3000-3,500	496,000	992,000

Tab. 12 NPV for Poplar per Different Rotation Periods.

	Rotation Periods		
	5 years	10 years	15 years
NPV(Som)	266,445.84	286,389.61	153,807.01

In an economically optimum forest rotation analysis, the decision regarding optimum rotation age is undertaken by calculating the maximum net present value (Avery and Burkhart, 2002). Based on the viability of the NPV, the maximum future financial gain is in its tenth year with a value of 286,389.61 Som. This is already considered to be the main current harvesting period in Kyrgyzstan.

ANOVA

The lowest elevation recorded was 546m and the highest elevation recorded was 2353m. A coding was formed with a 200 meter interval range which resulted in deriving 10 codes for the variables and corresponding diameter increment for analysis.

From the analysis of variance conducted, the lowest increment means were recorded for group 4-Juglans, 5-Juglans and 10-Poplar. It was observed that Poplar recorded a higher increment mean compared to Juglans even though the elevation for Poplar was much higher.

Site variations could be a factor but a key derivation also sterns from the fact that this is an indication that Poplar trees are able to withstand growth at high elevations compared to the other tree species in this study.

4. Discussion

Age and Biomass

With a quest to answer the research questions on biomass and allometric pattern, revenue and Biological Rotation Age, the following findings were made. Biomass and allometric relationship was deduced for all the four types of trees studied. However the deduction of revenue and biological rotation age was focussed on Poplar trees due to it being one of the most common and preferred tree species in Kyrgyzstan.

The suitable density for each tree species derived from previous work with similar site conditions was used to estimate the biomass content. To understand the parameters and the correlation among the different tree species, an age-biomass relationship was analysed for all four species of trees.

There was a significant trend of increasing age corresponding with increasing biomass for trees in similar site conditions.

Different age-biomass regression and suitable trendlines were obtained for the different tree species with the strongest trendline being for Acacia with a power regression of 0.79. A stronger association could have been obtained for age-biomass relationship within similar site conditions. This would have been particularly representative for Poplars and Juglans as they were collected over a large sample stand size of 18 and 6 respectively.

Out of the four tree species examined, the data for the Poplar trees were recorded over the most diverse sites and terrains. Data from comparable age range but different sites produced biomass of significant differences irrespective of similar age range (site 24 –Tup Lakeside and 26 Karakol Lakeside produced significantly higher biomass). The proximity of water body to the roots could be a reason for higher yield due to reduced competition for water resources. This study, however, did not examine the influence of the site condition on the growth of the trees.

A Factual Branch Analysis Model was conducted on 17 Poplar trees for the above-ground biomass. The model presented various weights of the tree segments of interest to local farmers. The wood weight is essential for timber and fuel, the branch being essential for firewood and the leaves for local farmers who may be interested in the usage for feeding their livestock. A conversion was done to cubic meter which is the dimension of sale of wood on the market. Conversion was also made from cubic metre to Kyrgyz Som to determine the current revenue of timber and the volume of trees amounting to a purchasable unit of 1cubic metre for sale in Kyrgyzstan.

It turned out that, the Juglans trees, which were the oldest set of trees recorded in this study, displayed a negative regression due to the ages of the tree with 40% of the trees above 100 years. Although recording high biomass figures, the mean annual increment analysed revealed a decrease after 70 years conforming to Avery and Burkhart, 2002 about mean annual increments decreasing with age after middle years.

This inflection point is however different from tree species and varies among different species. Juglans regia is a relatively slow growing tree but still pertinent for timber production because of its closely spaced annual growth rings, rich colour, and figure among other reasons. For a given species, larger and older trees are usually the most valuable for wood products (Ramage et al, 2017). In Kyrgyzstan, Juglans is not highly sought after for timber but if this were a preference, locals would have to notice the age that maximises the mean annual increment which in this study starts decreasing after 70 years.

A study conducted by Wallin et al (2008) on growing Walnut trees for profit reported that black walnut trees, when planted to maximize tree growth, can grow as much as 3 feet to 4 feet per year in good soil, reaching a mature height of over 100 feet and 30inches to 40inches in diameter, with 16″ diameter saw logs ready to harvest in 30 years.

The walnut trees in Kyrgyzstan were not studied with site conditions. Also, forest management practices were not examined and as such cannot be testified if the Walnut trees were grown to maximize tree growth as studied by Wallin et al (2008). Nevertheless, it is also possible that a cause for the decrease in periodic annual increment of the Juglans trees could be due to loss of tree volume due to injury or disease.

NPV

NPV was conducted for different rotation ages for a five-year interval between five to fifteen years for Poplar trees. The net present value conducted shows that the tenth year is the most profitable for timber harvest in terms of financial gain. Local farmers are already practising harvesting during this period. This may not necessarily be the age for biological rotation age for harvest if the objective is to maximize long-term wood production.

A study conducted by Subedi 2016 found that even though local farmers in Kyrgyzstan generally harvest Poplar trees after ten years, growth is increasing beyond ten years. Among the different stands he studied, fifteen years stand and eighteen years bore the highest yield thereby serving as the appropriate time for harvesting.

Nevertheless, even though the optimal rotation age for Poplar could be further beyond ten years, the current practice of harvesting Poplar at ten years is still a viable option as this gives a shorter rotation with less waiting time.

BRA

One of the most desirable features of Poplar is its fast-growing ability to be used for timber and biofuel. However, it is important to determine the biological rotation age since harvesting too early can compromise yield and harvesting too late will reduce the return on investment.

From the NPV calculated, it was deduced that the maximum financial return was on the tenth year of production. However, in order to determine the biological rotation age, the age at which the MAI reaches its maximum was considered. This is true only if the primary objective of the landowner is to maximize the volume production of the forest, with no regard to cost.

The shortest age range for suitable biological rotation age based on the climax of the mean annual increment was found to be 17 years at 2.95inches per year. A study by Miller and Bender, 2016, determined that the best yielding Poplar variety produced a respectable mean annual increment of 4.25 dry tons per acre. Faster growing varieties reached biological rotation age much faster (6-7 years) than slower growing varieties (8-10 years) which makes them even more suitable for commercial biomass plantation production systems.

The study by Miller and Bender was however focused on using Poplar for biomass relating to use as fuel for power generation. This dwelled on short-term rotation of Poplar and hence was not prioritized on timber generation.

5. Conclusion

The goal of this study is to determine the timber yields and corresponding non-timber forest product from four tree species in Kyrgyzstan. From the finding in this study, biomass content varies with age and a significant biomass variation was obtained even for trees with similar age range. However, increasing age corresponded with increasing biomass for trees in similar site conditions. Site-specific age-biomass model is therefore recommended since the tree allometry was found to differ significantly between sites even among same tree species. For Poplar trees, Tup (Lakeside and Karakol (Lakeside) recorded the highest average biomass. A deduction from this may be the proximity to a water body. Data recorded on the highest elevations of 2300 meters and above displayed the least increment and average biomass. Age –biomass relationship varied for the different tree species with the highest relation represented by power regression model with R^2 of 0.79 for Acacia tree species.

Net Present Value and Biological Rotation Age were deduced for Poplar as Poplar is among the most common and preferred tree species by locals. Different ages were represented for Net Present Value and for Biological Rotation Age. An ideal age of 10 displayed the highest net present value from a range of 5 year interval from 5 to 15 years. The ideal age for BRA, however, was around 17 years as this is the optimal time for rotation considering the maximum mean annual increment. It should be noted that the decision by locals for optimal harvesting time should be a personal decision whether based on the financial decision of ten years or durability and quality of wood of around 17 years.

This study recommends the further step for a specific site age-biomass and allometry study as this can make a significant influence on data and results.

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