Journal of

Agriculture Policy

(JAP)

CARI Journals

BIOECONOMIC POTENTIAL FOR SILVOPASTORAL AGROFORESTRY SYSTEM IN NORTH WALES

[1*]Michael Jide Nworji

Department of Forestry and Wildlife Management, Faculty of Agriculture, Chukwuemeka Odumegwu Ojukwu University, Igbariam Campus, Anambra State, Nigeria

Corresponding Author Email: mjnworji@gmail.com

Abstract

***Purpose**:* This study evaluated the bio-economic potentials of temperate lowland silvopastoral agroforestry systems in North Wales, United Kingdom.

***Methodology**:* The bioeconomic analysis compared three land-use plausible scenarios ('forestry', 'pasture / livestock' and 'agroforestry') at 3.5% discount rate on a 10-hectare farm over a 30-year rotation using discounted cash flow analysis and national costs and prices for both livestock and tree products based on 2016 baseline data. Base case net present value (NPV) and annual equivalent value (AEV) were calculated for each production livestock grazing, farm forestry, and silvopastoral agroforestry scenario, assuming no policy interventions.

Findings: Generally, results of the economic analyses indicated that under the baseline case, assuming no policy interventions, none of the options was viable. This study also showed that increase in lamb sale price, wood price, and wood yield improved the economic viability of the three investment options significantly. Again, the viability of the three investment options in this study is shown to decrease with increase in discount rates. Furthermore, this study disclosed that the application of prevailing government grant/subsidy schemes significantly improved the economic viability of the three investment options as livestock, forestry and agroforestry options showed positive NPV and AEV values at the baseline assumptions and are therefore adjudged economically viable as they all met the decision rule criteria for investment acceptance. Forestry was the most viable option with the highest NPV and AEV, followed by pasture/livestock and agroforestry options.

Unique contribution to theory, practice and policy: This study underscored the imperative need for policy makers to improve awareness of the benefits of grant incomes and address farmers' concerns about the economic viability of livestock, forestry and agroforestry investments. The results of this research will help promote greater awareness of the economic value of trees in extensively grazed landscapes in the United Kingdom as well as provide a basis for future comparisons and analysis of farm programs and ecosystem service markets.

Keywords: *agroforestry, silvopasture, forestry, livestock, bioeconomic*

INTRODUCTION

A silvopastoral system is a farming system that permits the coexistence of trees, pasture and animals on the same piece of land, combining long-term production of timber and fuelwood with yearly production of forage and livestock (Bergez *et al*., 1999). Silvopastoral systems are usually established to provide both timber and livestock products through the combination of pasture and widely spaced trees. Silvopastoral system integrates trees or shrubs with forage and animal production in the same unit of land for efficient utilisation of space, growing season, and growth factors. If properly managed, silvopastoral processes could improve pasture productivity and quality and provide sustained income with the simultaneous production of trees and grazing livestock.

Silvopastoral systems offer a variety of benefits for livestock management. Trees provide shade and wind protection, which reduce heat stress and wind-chill of livestock; performance is improved and mortality reduced. Economic returns from forage/livestock production continue while creating a sustainable system with environmental benefits. Such benefits of silvopastoral systems have been researched in the United Kingdom (UK) at the UK's Silvopastoral National Network Experiment (SNNE) since 1988. Sibbald and Dalziel (2000) reported that, in the UK's SNNE, no significant differences in lamb growth were observed between silvopastoral treatments and the pasture control until up to ten years after establishment of the sites (Sibbald and Dalziel, 2000). Results of the research at the silvopastoral system experiment at Henfaes, North Wales, have also shown that there was no significant difference in livestock production between silvopastoral treatments and the pasture control during the first six years of the tree establishment phase (Teklehaimanot *et al*., 2002). Pruning and thinning may be necessary to maintain agricultural production sustainably.

Although agroforestry experiments in the UK in the 1990s and the success of silvopasture in Northern Ireland have enhanced the biophysical and economic awareness of interactions in agroforestry systems, the commercial acceptance of these systems have remained a mirage, principally because of lack of will on the part of the Forestry Commission and other UK governmental units to promote agroforestry systems and the difficulty on the part of farmers to access some European Union (EU) agroforestry incentives and research programmes (Burgess, 2011). The financial viability is the major consideration in farmers' adoption of any land use investment options such as arable farming, agroforestry and forestry, as relative costs and returns are greatly influenced by local differences in yields, prices and government grants (Graves *et al*., 2011).

Silvopastoral system may be more advantageous to farmers than non-agroforestry farm management system as the tree-based grazing system could be more resilient to fluctuations in market price and other bioeconomic variables, and could provide the farmer with reasonable level of financial profit and cash flow. Presently, little is known about the economic opportunities and risks associated with operating silvopastoral agroforestry enterprises. There is a general perception among farmers that investments in agroforestry or farm forestry will offer little or no economic returns and will be unsuccessful (e.g. Burton and Wilson 2000). Their general acceptance depends on developing and promoting systems that produce financial returns that are at least equal to those obtained from the annual crops they would replace. However, little research has compared returns from silvopastoral agroforestry, farm forestry, and conventional livestock grazing in the United Kingdom.

It would be interesting to know whether a silvopastoral agroforestry system could produce better financial and environmental outcomes compared with pure forestry and extensive grazing-only systems. This study, therefore, sought to appraise the bioeconomic potentials of temperate lowland silvopastoral agroforestry systems in the United Kingdom. To achieve this aim, a bio-economic analysis was conducted to evaluate conventional grazing systems against preferred silvopastoral agroforestry systems for temperate lowland system in North Wales, United Kingdom. The study is based on the premise that silvopastoral agroforestry system is a viable undertaken compared to a pasture or forestry system,

The results of this research will contribute directly to the goals of the UK's Silvopastoral National Network Experiment through a better understanding of the bio-economic potential for silvopastoral agroforestry development in the lowland areas of North Wales. The findings will also help promote greater awareness of the economic value of trees in extensively grazed landscapes in North Wales and should assist future investment decisions by landowners. Furthermore, the study is in line with the Wales "100,000 Hectare Challenge" in which the

Welsh Government seek to increase the woodland cover of Wales from the present 14 percent to 20 percent over the next 20 years, with a view to achieving a net increase in carbon sequestration to combat climate change (Osmond and Upton, 2012; Glastir Woodland Creation, 2016). To achieve this goal will require planting an average of 5,000 hectares of woodland a year. These goals are particularly relevant in a UK context since there is a general perception amongst landowners that trees compete strongly with pasture and livestock production and are considered an economic liability rather than as a potential asset.

MATERIAL AND METHODS

The scenarios

The study compared the economic viability of three farm management systems using discounted cash flow analysis and national costs and prices for both livestock and tree products. The following three farming enterprise scenarios were considered:

Scenario 1: Conventional lowland sheep spring lambing system - treeless sheep-grazed pasture farm

Scenario 2: Forestry woodland system – 2500 stem ha^{-1} red alder forestry woodland with no grazing.

Scenario 3: Silvopastoral agroforestry system – 200 stem ha^{-1} red alder (*Alnus rubra* Bong) trees planted into sheep grazed pasture farm.

These farm management systems are the major components of the UK's National Network Experiments at six sites established across the country investigating the potential of silvopastoral agroforestry on UK farms (Teklehaimanot et al. 2002). Although average farm size in the UK is 57 hectares, this study has chosen one hectare as a basis for comparison in this appraisal. It is pertinent to emphasise that there was a financial optimization of the scenarios under consideration with a view to finding the system that would give the highest net benefit. Major tasks undertaken included the development of the farm budgets and cash flow plans. These involved detailed listing of all possible sources of revenues, variable costs and fixed costs including their time dimension.

Sources of financial data

Farm establishment and maintenance costs, and tree growth data were secured from the Henfaes Silvopastoral Network Experiment while prevailing costs, returns, and price data were adapted from the John Nix Farm Pocketbook (46th Edition, 2016) (Redman, 2015), the Farm Management Handbook (36th Edition, 2015/16) (SAC, 2014), the Department for Environment, Food & Rural Affairs (DEFRA) statistics, the Forestry Commission, and from various relevant online resources. It is pertinent to note that these data are only approximations of real individual farms present circumstances and conditions.

Phases of economic analysis

The phases of the economic analysis were:

- Definition of costs, revenues
- Development of farm budgets for the scenarios
- Construction of cash flows based on the farm budgets
- Discounting cash flows using prevailing lending discount rate
- Analysis of the discounted cash flow using two measures of project worth, the net present value (NPV) and the annual equivalent value (AEV)
- Sensitivity analysis

Journal of Agricultural Policy
ISSN 2520 -7548 (Online)
Vol 2, Issue No.1, Pp 42 - 66 , 2020
www.carijournals.org

The study focused mainly on enterprise budget, financial projection, and valuation measurements framework to arrive at overall evaluation of the systems. A 30-year projection on a one-hectare basis was made for each of the three models. All the costs and revenues expected for each system were detailed in the enterprise budgets which were later combined into cash flow plans with time dimension added. The methods of enterprise budget process suggested by earlier researchers (Godsey 2008; Soeleman *et al*., 2014) were employed. The comparisons were initially made without consideration for government grant/subsidy.

Farm enterprise budget

The farm budgets presented below describes the costs and returns associated with each of the three scenarios and include information on the returns generated from the enterprises and costs such as livestock/pasture management costs, tree planting, maintenance, harvesting, labour, power and machinery, rent and finance costs, and overhead (Chase, 2006; Doye, 2007).

Scenario 1: Conventional lowland sheep spring lambing system

Analysis of the conventional treeless sheep grazing pasture system exemplified the economic performance of a typical mid-sized commercial family sheep farming enterprise commonly found in the UK. This scenario modelled the economic viability of lowland spring lambing system, organised to maximise the utilisation of pasture and, where lambs were sold off grass. The system generated income from the annual sale of lambs, wool, and cull ewes and rams. Income from lamb sales was also considered as income earned from pasture since pasture was used for grazing the sheep in order to sell the meat of lamb.

Conventional lowland sheep spring lambing system assumptions

The general assumptions of the net cash flow for the conventional lowland sheep grazing system are as follows:

a) The performance data, costs of inputs and outputs, and prices of product sales are known and remain constant over the 30-year projection period.
b) All costs were incurred from year 1 through to year 30 while revenues were spread from year 2 to year 30 (model assumption).
c) Mixed breeds of mature 100 ewes and 2 rams were introduced into improved permanent pasture in year one at a stocking rate of 10 ewes per hectare and 1 ram per 45 ewes (Redman, 2015).
d) Average lamb sale liveweight of 41kg was assumed. 155 lambs were sold per 100 ewes put ram at a market price of £66.7/head (Redman, 2015).
e) 20% of the ewe flock is culled yearly at £65 each, allowing for 4% mortality (Redman, 2015).
f) 23% of ewes are bought or home-raised at £145. Ram was purchased for £480 per head and sold at £75 after 3.5-year life. (Redman, 2015).
g) Variable costs for veterinary and medicine include allowance for wormer, vaccine, treatments for flies and feet.
h) Miscellaneous costs include contract shearing @ £1.49/ewe, scanning £1.00/ewe and ewe and lamb tags £1.49/ewe, carcass disposal £0.56/ewe, straw £1.47/ewe, minerals and licks etc. £2.05/ewe, marketing levy and transport £6.10/ewe (Redman, 2015).
i) Forage costs are based on improved permanent pasture (£147/hectare) (Redman, 2015)
j) Fencing costs include stock proof post and 4-barb @ £5/metre, dug in rabbit proof up to £6.90/metre (per side), and post and 3 rails £13.75/metre (Redman, 2015).
k) Fixed costs include labour (paid and unpaid), running costs of power and machinery, rent and finance costs, general overhead costs and farm maintenance (Redman, 2015).

l) The market is assumed to be perfect, the discount rate of 3.5% (H.M Treasury, 2003) remains constant over the projection period, and cash flows are expressed in British pound sterling.
m) Grants/subsidies were not included in the analysis.

The assumptions and budgetary requirements for livestock production system are summarised in Table 1.

Table 1**:** Budget for Livestock Production

	Performance data	
	Farm size (ha)	10
	Number of ewe	100
	Number of ram (1 ram to 45 ewes)	2.22
	Stocking rate (ewes per hectare)	10
	Ewe culling rate	20%
	Ram Replacement Rate	23%
	Fleece weight per ewe (kg)	2
	Lamb sold per 100 ewes put to ram	155
	Average price per lamb (£)	£66.70
Year	**Revenue:**	**Total (£)**
2 to 30	Lamb Sales (£66.7 per 1.55 lamb	£29,981.65
2 to 30	Wool (2kg/ewe @ £1.20/kg)	£696.00
2 to 30	Cull Ewes and Ram	£3,915.00
	Total Revenue	**£34,592.65**
	Variable costs:	
1 to 30	Ewe and Ram Replacement @ 23%	£10,920.00
1 to 30	Concentrates @ £13.30/head	£3,990.00
1 to 30	Vet and Medical Fees @ £10.90/head	£3,270.00
1 to 30	Miscellaneous @ £14.10/head	£4,230.00
1 to 30	Forage Cost (inc. bought in forage and keep)	£4,410.00
	Total Variable Costs	**£26,820.00**
	Fixed costs:	
1 to 30	Labour (paid)	£1,050.00
1 to 30	Labour (unpaid)	£14,100.00
1 to 30	Power and machinery (running costs)	£6,660.00
1 to 30	Miscellaneous fixed costs (Overheads)	£3,150.00
1 to 30	Rent and Finance Costs	£2,250.00
	Total Fixed Costs	**£27,210.00**
	Less unpaid labour	£13,110.00
	Total Costs	**£39,930.00**
	Net Cash Flow	**-£5,337.35**

Journal of Agricultural Policy
ISSN 2520 -7548 (Online)
Vol 2, Issue No.1, Pp 42 - 66 , 2020
www.carijournals.org

Scenario 2: Forestry system

This scenario is reflective of the farm woodland control of the National Network Experiment or the shift from the traditional upland conifers' establishment towards the re-establishment of broadleaved woodland in the lowlands of the UK using red alder (Teklehaimanot *et al*., 2002).

Forestry woodland system assumptions

The general assumptions of the net cash flow for the forestry woodland system are as follows:

a) It is assumed that Red alder was established at 2m x 2m spacing and stocking density of 2500 stem ha^{-1}, growing at a maximum annual increment of 12 m^3 per hectare per year, i.e., at yield class of 12, and maintained on a 30-year firewood and sawlog rotation with no grazing.
b) Tree establishment costs include site preparation, tree planting, protection, and maintenance. Harvesting costs include the costs of marking up for thinning and final harvesting. While fixed costs include labour, running costs of power and machinery, general overhead costs, and rent and finance costs.
c) Intermediate thinning was done at age 15 while final harvest occurred in year 30.
d) All operations were assumed to be executed by contractors and all timber sales were done through standing sales (both thinning operations and final harvest).
e) Harvesting revenues were estimated by assigning volume yield to fuelwood and sawlog and multiplying by assumed flat standing sale price of £30/m3 for both fuelwood and sawlog.
f) Grants/subsidies were not included in the analysis.
g) The market is assumed to be perfect, the discount rate of 3.5% (H.M Treasury, 2003) remains constant over the projection period, and cash flows are expressed in British pound sterling.
h) Revenues from the sale of firewood and sawlog, establishment costs, operating costs, and fixed costs are shown in the budgetary requirements for 2500 stem ha^{-1} red alder block (Table 2).

Table 2: Budget for 2500 stem ha^{-1} red alder Block

Year	Phase / Activities	Total (£)
	Revenues:	
15	Thinning (standing sale) (312 m^3 @ £30/m^3)	£9,360.00
30	Final harvest (standing sale) (506 m^3 @ £30/m^3)	£15,180.00
	Total Revenues	**£24,540.00**
	Variable Costs	
	1. Establishment:	
1	**a. Site Preparation**	
1	(i). Fencing (materials @ £1.48/m and labour @ £15/hr)	£592.00
1	(ii). Ground preparation @ £99.00/ha	£99.00
1	(iii). Marking out/Staking @ £0.04/spot x 2500 spots	£100.00
1	**b. Tree Planting**	
1	(i). Purchase of 2500 red alder plants @ £0.40/plant	£1,000.00
1	(ii). Spot spraying of herbicides @ £0.10/spot x 2500 spots	
1	(1-metre-wide spot)	£250.00
1	(iii). Hand planting 2500 plants @ £0.60/plant (including cost	
1	of guards/shelters)	£1,500.00
1	**c. Tree Protection**	
1	(i). 2500 tree shelters/plastic tubes plus ties @ £0.55 each	£1,375.00

1	(ii). Anchor peg plus tie @ £0.30 each x 2500 trees	£750.00
	2. Maintenance:	
	a. Beating up	
2, 3	(i). Operation @ £300/ha	£600.00
2, 3	(ii). Plant supply @ £200/ha	£400.00
	b. Weeding	
1, 2, 3	(i). Spot weeding with herbicide @ £100/ ha	£300.00
	c. Pruning @ £250/ha	£750.00
	3. Harvesting:	
	(i). Marking-up Thinning (312 m^3 @ £1/m^3)	£312.00
	(ii). Marking-up Clear felling (506 m^3 @ £1/m^3)	£506.00
	Total Variable Costs	**£8,534.00**
	Fixed Costs	
1 to 30	a. Labour	£750.00
1 to 30	b. Power and machinery (running costs)	£2,700.00
1 to 30	c. Miscellaneous fixed costs (Overheads)	£3,000.00
1 to 30	d. Rent and finance costs	£2,250.00
	Total Fixed Costs	**£8,700.00**
	Total Costs	**£17,234.00**
	Net Cash Flow	**£7,306.00**

Scenario 3: Agroforestry system

The general assumptions of the net cash flow for the agroforestry system were:

a) The agroforestry system was established on existing improved permanent pasture consisting of a mixture of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) and grazed rotationally. There was therefore no reseeding of the pasture.

b) Red alder (*Alnus rubra* Bong.) was introduced into the improved permanent pasture at 5m x 5m spacing and stocking density of 200 stem ha^{-1} and maintained on a 30-year firewood and sawlog rotation.

c) The trees were pruned at ages 10, 15, and 20 while commercial thinning was conducted at ages 10 and 20 to open up the canopy for greater solar penetration to understory pasture, to improve the growth and value of the block, and to provide periodic income for the farmer (Sibbald, 2006). The block was clear-felled in year 30.

d) Tree establishment costs included those for site preparation, tree planting, protection, and maintenance. Harvesting costs included the costs of marking up for thinning and final harvesting. While fixed costs included labour, running costs of power and machinery, general overhead costs, and rent and finance costs,

e) It is assumed all operations were carried out by contractors and all timber sales were done through standing sales (both thinning operations and final harvest).

f) Harvesting revenues were estimated by assigning volume yield to fuelwood and sawlog and multiplying by assumed flat standing sale price of £30/m^3 for both fuelwood and sawlog.

g) Crown area is assumed to be negligible for the first 10 years with no negative impact on pasture productivity, that from year 11 to year 20, crowns increased to occupy 30% of the area (viewed from above) resulting in a loss of 30% of Area Payment by year 20, and that crown growth and crown area remained constant after year 20.

h) The livestock component for the silvopastoral system was simulated using the information for the conventional pasture system of scenario 1. Sheep were introduced into the system in year two to allow time for forage and tree stabilisation. Revenues from sheep production was received from year 2 to 30. The sheep rearing performance data, pricing, revenues, establishment costs, maintenance costs, and fixed costs remain the same as for the sheep production.

i) Government grants/subsidies were not considered in this analysis.
j) The market is perfect, the discount rate of 3.5% remains constant over the projection period, and cash flows are expressed in British pound sterling.

The assumptions and budgetary requirements for agroforestry system are presented in Table 3.

Growth and yield data

As yield model specific for red alder especially for a Silvopastoral National Network Experiment setting in the UK is non-existent at present, the best estimate of harvest yields per hectare over the long term were obtained by using inventory data from Henfaes SNNE and applying the biomass equation developed specifically for open-grown red alder trees in Silvopasture (Nworji, 2019). A sensitivity analysis was also conducted to consider what difference to the results this would make if other magnitude above or below the best estimates were assumed. The predicted harvest yields for forestry and agroforestry systems are shown in Tables 2 and 3, respectively.

Economic modelling

Cash flow budget

Cash flow budgets for the three scenarios were developed based on the annual estimated costs and returns developed in the enterprise budgets. The cash flow budgets indicated when payments and returns occurred over time as well as provided clear pictures of future financial commitments and viability of the enterprises. The net cash flow was determined by subtracting the streams of total costs from the stream of total returns.

Discounted cash flow

Since a future amount of money is worth less in the present a discounting technique is often used to bring future costs and returns to a present-day value. To bring the streams of these future costs and returns to their present value a standard real discount rate of 3.5% was adopted based on recommendations in the Treasury Green Book (HM Treasury, 2003), UK central government's policy evaluation guide book (Davies and Kerr, 2015), which states that:

"Society as a whole prefers to receive goods and services sooner rather than later, and to defer costs to future generations. This is known as 'social time preference'; the 'social time preference rate' (STPR) is the rate at which society values the present compared to the future." "This guidance recommends that the STPR be used as the standard real discount rate." (H.M Treasury, 2003).

In addition to the baseline standard discount rate of 3.5%, the rates of 0%, 5%, and 8% were also investigated. Using the adopted discount rates, discount factors were calculated to discount future costs and returns of the enterprises back to the present in pound sterling. The discount factor was calculated using the following formula:

$$DF = \frac{1}{(1+r)^t}$$

Where r = discount rate and t = number of years money was held.

It is customary for the discount factor to decrease rapidly with time, due to the compounding of the discount rate.

Journal of Agricultural Policy
ISSN 2520 -7548 (Online)
Vol 2, Issue No.1, Pp 42 - 66 , 2020
www.carijournals.org

Table 3**:** Budget for Agroforestry System

Year	Phase / Activities	(£)/Unit	Total (£)		Year		(£)/Unit	Total (£)
	Revenues:					**2. Maintenance:**		
2 to 30	Lamb Sales (£66.70 per 1.55 lamb	£1,033.85	£29,981.65		2, 3	(i). Plant supply @ £120/ha + Beating up @	£137.00	£274.00
2 to 30	Wool (2kg/ewe @ £1.20/kg)	£24.00	£696.00		1, 2, 3	(ii). Spot weeding with herbicide @ £100/ha/yr	£100.00	£300.00
2 to 30	Cull Ewes and ram	£135.00	£3,915.00		10, 15, 20	(iii). Pruning	£100.00	£300.00
10	1st Thinning (standing sale) (22 m^3 @ £30/m^3)	£660.00	£660.00			**3. Harvesting:**		
20	2nd Thinning (standing sale) (25.20 m^3 @ £30/m^3)	£756.00	£756.00		10	(i). Marking-up 1st thinning (22 m^3 @ £1/m^3)	£22.00	£22.00
30	Final harvest (standing sale) (81 m^3 @ £30/m^3)	£2,430.00	£2,430.00		20	(ii). Marking-up 2nd thinning (25.20 m^3 @ £1/m^3)	£25.20	£25.20
	Total Revenue	**£5,038.85**	**£38,438.65**		30	(iii). Marking-up clear fell (81 m^3 @ £1/m^3)	£81.00	£81.00
					1 to 30	4. Livestock/Pasture Management	£894.00	£26,820.00
	Variable Costs:					**Total Variable Costs**	**£2,974.20**	**£29,437.20**
	1. Establishment:							
	a. Site Preparation					**Fixed Costs:**		
1	(i). Fencing (materials @ £1.48/m	£592.00	£592.00		1 to 30	a. Labour	£35.00	£1,050.00
1	(ii). Ground preparation @ £99.00/ha	£85.00	£85.00		1 to 30	b. Power and machinery (running costs)	£222.00	£6,660.00
1	(iii). Marking out/Staking @ £0.04/spot x 200 spots	£8.00	£8.00		1 to 30	c. Miscellaneous fixed costs (Overheads)	£102.00	£3,060.00
	b. Tree Planting				1 to 30	d. Rent and finance costs	£75.00	£2,250.00
1	(i). Purchase of 200 red alder plants @ £0.60/plant	£120.00	£120.00			**Total Fixed Costs**	**£434.00**	**£13,020.00**
1	(ii). Spot spraying of herbicides @ £0.10/spot x 200 spots	£20.00	£20.00			**Total Costs**	**£3,408.20**	**£42,457.20**
1	(iii). Hand planting 200 plants @ £0.60/plant	£120.00	£120.00					
	c. Tree Protection					**Net Cash Flow**	**£1,630.65**	**-£4,018.55**
1	(i). 200 tree shelters/tubes plus ties @ £0.65 each	£130.00	£130.00			**NPV**		**-£4,254.58**
1	(ii). Supporting pressure-treated wooden fence posts	£480.00	£480.00			**AEV**		**-£231.33**
1	(iii). Anchor peg plus tie @ £0.30 each x 200 trees	£60.00	£60.00					

Journal of Agricultural Policy
ISSN 2520 -7548 (Online)
Vol 2, Issue No.1, Pp 42 - 66 , 2020 www.carijournals.org

Discounted cash flow analysis

Given the information provided in the discounted cash flow budgets, the net present value (NPV) and the annual equivalent value (AEV) measures of enterprise worth were used to measure and compare the economic viability of the three systems. The same starting point of Year 1 and projection duration of 30 years were used for all comparisons.

Net present value (NPV)

Net present value is simply a technique where all future net income streams from the enterprise are discounted to reflect their current or present value (PV). The NPV is the primary criterion adopted by the UK government for deciding whether action can be justified. Since estimates are used, rather than exact costs and returns, NPV can be used as a ranking tool in capital budgeting to analyze and compare the profitability of a projected investment or project alternatives, such as agroforestry, livestock or forestry investments, to see which option is the most economically attractive. The NPV was calculated as the sum of the discounted cash flows using the recommended standard discount rate of 3.5% and the formula shown in Equation [1]:

$$NPV = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} \qquad \text{……………………. [1]}$$

where, B_t = Benefits in each project year t, C_t = Costs in each project year t, n = Number of years to the end of project (n ranges from 1 to 30), and r = Discount rate (3.5%)

The formula indicates that the NPV of an investment is determined by discounting all future benefits (B_t) and costs (C_t) to the present with interest rate (r), and the NPV value is calculated as the difference between the present value of cash inflows and the present value of cash outflows.

The calculated NPV may work out to be a negative or positive value or zero. A positive NPV result (where NPV > 0) means that, at the discount rate assumed, the present value of the benefit streams is greater than the present value of the cost stream - that is, sufficient to recover investment and should be accepted because it is profitable. On the other hand, a negative NPV value (where NPV < 0) indicates that discounted costs exceed discounted benefits. Such an alternative should be rejected because it does not generate enough benefit to offset costs and will result in a financial loss. A zero NPV value (where NPV = 0) shows that discounted benefits equal discounted costs and the investment should be accepted because it still generates enough benefits to offset costs – this referred to as the financial break-even point (Godsey *et. al*., 2009). The formal selection criterion for the NPV measure of project worth is to accept all investments with the higher positive NPV.

Annual equivalent value (AEV)

The AEV is another common discounted measure of economic performance used in capital budgeting to broadly compare investments options that have varying maturity (Godsey 2008). The calculated NPV can be used to derive the AEV (equivalent yearly income from each investment option) for an investment. AEV has been described as NPV expressed as an annual amount, that is, the property-owner’s yearly incomes per hectare that is usually used to compare the economic earnings from various land uses that produce yearly incomes (Bullard and Straka, 1998). It looks at the expected income potentials of alternative investments by estimating and establishing the constant annual cash flow generated by an investment over its lifespan. The generated present value of the constant annual cash flow is equal to the NPV of the investment. Decision criterion is to accept investment with higher AEV.

Annual equivalent value was calculated using the formula as shown in equation [3]:

$$AEV = r(NPV) / (1 - (1 + r)^{-n}) \quad \ldots\ldots [3]$$

where,

NPV = net present value

r = rate per investment period

n = number of years in investment periods

Sensitivity analysis

Sensitivity analysis was conducted to examine the effects of varying the following factors:

a) Lamb price – the baseline lamb price of £66.7/head was increased and decreased by 50%, respectively.
b) Fuelwood and sawlog prices - the baseline red alder fuelwood and sawlog prices were increased and decreased by 50%, respectively.
c) Tree harvest volume – the baseline yields of harvested red alder in agroforestry and forestry systems were increased and decreased by 50%, respectively.
d) Discount rate – the baseline discount rate of 3.5% was substituted for discount rates of 0%, 5%, and 8%, respectively.
e) Grant/Subsidy – the NPV, and AEV of the three scenarios were recalculated with the application of the Basic Payment Scheme (BPS) subsidy to both livestock and agroforestry scenarios, and the Welsh Government Glastir New Planting Payment and Woodland Creation Premium for the forestry scenario. These are presented in section 1.4.5 (Sensitivity to grant/subsidies).

RESULTS

Economic indicator analysis

The Net Cash Flow (NCF), Net Present Value (NPV), and Annual Equivalent Value (AEV) measures of investment appraisals were used as financial indicators to quantify and compare the economic viability of Livestock, Forestry, and Agroforestry investment options based on 2016 baseline data. The results of the evaluation are summarised in Table 4.

Table 1: Summary of present value (PV), net present value (NPV) and annual equivalent value (AEV) of livestock, forestry and agroforestry scenarios at baseline discount rate of 3.5%, on a 10-hectare farm, over a 30-year rotation, assuming no subsidy.

Scenario	PV of Revenue	PV of Cost	NPV	AEV
Livestock	£20,786.44	£24,479.81	-£3,693.37	-£200.81
Forestry	£10,995.20	£12,824.58	-£1,829.38	-£99.47
Agroforestry	£22,500.02	£26,754.60	-£4,254.58	-£231.33

Journal of Agricultural Policy
ISSN 2520 -7548 (Online)
Vol 2, Issue No.1, Pp 42 - 66 , 2020

Net cash flow

Using the baseline discount rate of 3.5%, the estimated discounted net margins over a rotation period of 30 years under the present assumptions are presented in Tables 5, 6, and 7 for Livestock, Forestry, and Agroforestry options, respectively. The trends indicate that the livestock option generated negative NCF all through the 30-year rotation with a negative total net margin of -£5,337.35 (Table 5 and Figure 1). NCF for the forestry option was positive only in year 15 (£8,508.00) and year 30 (£14,384.00) for a positive total net margin of £7,306.00 (Table 6 and Figure 1) while the agroforestry option generated positive NCF only in year 10 (£402.85), in year 20 (£495.65), and in year 30 (£2,213.85) for a negative total net margin of -£4,018.55 (Table 7 and Figure 1).

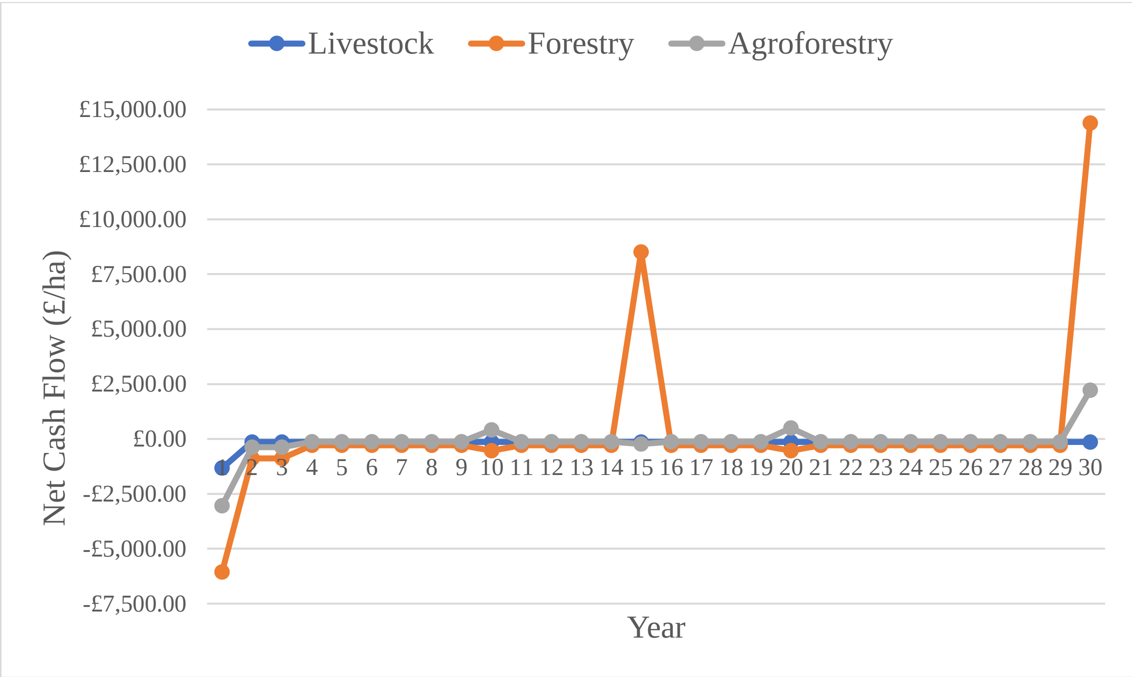

Figure 1: Net Cash Flow for livestock, agroforestry, and forestry over a rotation of 30 years

Table 2: Discounted benefits and costs for Livestock scenario at 3.5% discount rate on a 10-hectare farm over a 30-year rotation, assuming no subsidy.

Year	Revenue	Cost	Net margin	Discounted net margin
1	£0.00	£1,331.00	-£1,331.00	-£1,285.99
2	£1,192.85	£1,331.00	-£138.15	-£128.96
3	£1,192.85	£1,331.00	-£138.15	-£124.60
4	£1,192.85	£1,331.00	-£138.15	-£120.39
5	£1,192.85	£1,331.00	-£138.15	-£116.32
6	£1,192.85	£1,331.00	-£138.15	-£112.39
7	£1,192.85	£1,331.00	-£138.15	-£108.58
8	£1,192.85	£1,331.00	-£138.15	-£104.91
9	£1,192.85	£1,331.00	-£138.15	-£101.36

10	£1,192.85	£1,331.00	-£138.15	-£97.94
11	£1,192.85	£1,331.00	-£138.15	-£94.63
12	£1,192.85	£1,331.00	-£138.15	-£91.43
13	£1,192.85	£1,331.00	-£138.15	-£88.33
14	£1,192.85	£1,331.00	-£138.15	-£85.35
15	£1,192.85	£1,331.00	-£138.15	-£82.46
16	£1,192.85	£1,331.00	-£138.15	-£79.67
17	£1,192.85	£1,331.00	-£138.15	-£76.98
18	£1,192.85	£1,331.00	-£138.15	-£74.37
19	£1,192.85	£1,331.00	-£138.15	-£71.86
20	£1,192.85	£1,331.00	-£138.15	-£69.43
21	£1,192.85	£1,331.00	-£138.15	-£67.08
22	£1,192.85	£1,331.00	-£138.15	-£64.81
23	£1,192.85	£1,331.00	-£138.15	-£62.62
24	£1,192.85	£1,331.00	-£138.15	-£60.50
25	£1,192.85	£1,331.00	-£138.15	-£58.46
26	£1,192.85	£1,331.00	-£138.15	-£56.48
27	£1,192.85	£1,331.00	-£138.15	-£54.57
28	£1,192.85	£1,331.00	-£138.15	-£52.73
29	£1,192.85	£1,331.00	-£138.15	-£50.94
30	£1,192.85	£1,331.00	-£138.15	-£49.22
Total	**£34,592.65**	**£39,930.00**	**-£5,337.35**	**-£3,693.37**

Table 3: Discounted benefits and costs for Forestry scenario at 3.5% discount rate on a 10-hectare farm over a 30-year rotation, assuming no subsidy.

Year	Revenue	Cost	Net margin	Discounted net margin
1	£0.00	£6,056.00	-£6,056.00	-£5,851.21
2	£0.00	£890.00	-£890.00	-£830.82
3	£0.00	£890.00	-£890.00	-£802.73
4	£0.00	£290.00	-£290.00	-£252.72
5	£0.00	£290.00	-£290.00	-£244.17
6	£0.00	£290.00	-£290.00	-£235.92
7	£0.00	£290.00	-£290.00	-£227.94
8	£0.00	£290.00	-£290.00	-£220.23
9	£0.00	£290.00	-£290.00	-£212.78
10	£0.00	£540.00	-£540.00	-£382.82
11	£0.00	£290.00	-£290.00	-£198.63
12	£0.00	£290.00	-£290.00	-£191.92

13	£0.00	£290.00	-£290.00	-£185.43
14	£0.00	£290.00	-£290.00	-£179.16
15	**£9,360.00**	**£852.00**	**£8,508.00**	**£5,078.35**
16	£0.00	£290.00	-£290.00	-£167.24
17	£0.00	£290.00	-£290.00	-£161.59
18	£0.00	£290.00	-£290.00	-£156.12
19	£0.00	£290.00	-£290.00	-£150.85
20	£0.00	£540.00	-£540.00	-£271.39
21	£0.00	£290.00	-£290.00	-£140.82
22	£0.00	£290.00	-£290.00	-£136.05
23	£0.00	£290.00	-£290.00	-£131.45
24	£0.00	£290.00	-£290.00	-£127.01
25	£0.00	£290.00	-£290.00	-£122.71
26	£0.00	£290.00	-£290.00	-£118.56
27	£0.00	£290.00	-£290.00	-£114.55
28	£0.00	£290.00	-£290.00	-£110.68
29	£0.00	£290.00	-£290.00	-£106.94
30	**£15,180.00**	**£796.00**	**£14,384.00**	**£5,124.71**
Total	**£24,540.00**	**£17,234.00**	**£7,306.00**	**-£1,829.38**

Table 4: Discounted benefits and costs for Agroforestry scenario at 3.5% discount on a 10-hectare farm over a 30-year rotation, assuming no subsidy.

Year	Revenue	Cost	Net margin	Discounted net margin
1	£0.00	£3,043.00	-£3,043.00	-£2,940.10
2	£1,192.85	£1,565.00	-£372.15	-£347.41
3	£1,192.85	£1,565.00	-£372.15	-£335.66
4	£1,192.85	£1,328.00	-£135.15	-£117.78
5	£1,192.85	£1,328.00	-£135.15	-£113.79
6	£1,192.85	£1,328.00	-£135.15	-£109.94
7	£1,192.85	£1,328.00	-£135.15	-£106.23
8	£1,192.85	£1,328.00	-£135.15	-£102.63
9	£1,192.85	£1,328.00	-£135.15	-£99.16
10	**£1,852.85**	**£1,450.00**	**£402.85**	**£285.59**
11	£1,192.85	£1,328.00	-£135.15	-£92.57
12	£1,192.85	£1,328.00	-£135.15	-£89.44
13	£1,192.85	£1,328.00	-£135.15	-£86.42
14	£1,192.85	£1,328.00	-£135.15	-£83.49
15	£1,192.85	£1,428.00	-£235.15	-£140.36
16	£1,192.85	£1,328.00	-£135.15	-£77.94

17	£1,192.85	£1,328.00	-£135.15	-£75.31
18	£1,192.85	£1,328.00	-£135.15	-£72.76
19	£1,192.85	£1,328.00	-£135.15	-£70.30
20	**£1,948.85**	**£1,453.20**	**£495.65**	**£249.10**
21	£1,192.85	£1,328.00	-£135.15	-£65.62
22	£1,192.85	£1,328.00	-£135.15	-£63.41
23	£1,192.85	£1,328.00	-£135.15	-£61.26
24	£1,192.85	£1,328.00	-£135.15	-£59.19
25	£1,192.85	£1,328.00	-£135.15	-£57.19
26	£1,192.85	£1,328.00	-£135.15	-£55.25
27	£1,192.85	£1,328.00	-£135.15	-£53.39
28	£1,192.85	£1,328.00	-£135.15	-£51.58
29	£1,192.85	£1,328.00	-£135.15	-£49.84
30	**£3,622.85**	**£1,409.00**	**£2,213.85**	**£788.75**
Total	**£38,438.65**	**£42,457.20**	**-£4,018.55**	**-£4,254.58**

Present value, net present value, and annual equivalent value

The evaluation of the viability of livestock, forestry, and agroforestry land use scenarios were also compared in terms of present value (PV), NPV and AEV per hectare at the baseline discount rate (DR) of 3.5% as shown in Table 4. Results show that under the baseline assumption, the PV of costs for all the three investment options were higher than the PV of their respective revenues resulting in negative values for their respective NPVs and AEVs and are therefore adjudged unviable. Agroforestry option incurred the highest loss with an NPV of -£4,254.58 and an AEV of -£231.33, followed by livestock option with an alternate NPV of -£3,693.37 and an AEV of -£200.81. Forestry option incurred the least loss with an alternate NPV of -£1,829.38 and an AEV of -£99.47 (Table 4).

Generally, the three scenarios indicated negative values at the baseline assumptions and are adjudged economically unviable as they all failed to meet the decision rule criteria for investment acceptance. The negative values are indication that the revenues are insufficient to offset the investment costs and therefore engagement in these investments would certainly lead to financial losses.

Negative NPV (NPV < 0) indicates the generation of insufficient revenue to offset the costs of establishment and management, which in Agroforestry option include the cost of tree/livestock management. Negative AEV indicates that all the three scenarios would accrue quite significant annual losses per hectare throughout the 30-year rotation period.

Sensitivity analysis of results

Sensitivity to variations in lamb sale price

Changes in investment values as a result of a 50% increase and decrease in the price of lamb on NPV and AEV are presented in Table 8. The result shows that both agroforestry and livestock options are sensitive to changes in lamb price. Livestock remains the most preferred option with higher NPV and AEV followed again by agroforestry and forestry options in that order. For instance, a 50% increase in the price of lamb increased the NPV of livestock option from -

£3,693.00/hectare to £5,314.00/hectare, while the NPV of agroforestry option increased from -£4,255.00/hectare to £4,753.00/hectare, The NPV and AEV of forestry option remained constant in this analysis.

On the other hand, a 50% reduction in the price of lamb significantly altered the relative economic viability of the investment options by reducing the NPV of livestock from -£3,693.00/hectare to -£12,701.00/hectare and the NPV of agroforestry option from -£4,255.00/hectare to -£21,369.00/hectare thereby rendering both livestock and agroforestry options economically unattractive.

Table 5: Sensitivity of net present value (NPV) and annual equivalent value (AEV) per hectare to variation in lamb sale price, wood price, and wood yield at baseline discount rate of 3.5%

Parameters	**Livestock**		**Forestry**		**Agroforestry**	
	NPV	AEV	NPV	AEV	NPV	AEV
Base value	-£3,693.00	-£201.00	-£1,829.00	-£99.00	-£4,255.00	-£231.00
Lamb price +50%	£5,314.00	£289.00	-£1,829.00	-£99.00	£4,753.00	£258.00
Lamb price -50%	-£12,701.00	-£691.00	-£1,829.00	-£99.00	-£21,369.00	-£1,162.00
Wood price +50%	-£3,693.00	-£201.00	£3,668.00	£199.00	-£3,398.00	-£185.00
Wood price -50%	-£3,693.00	-£201.00	-£7,327.00	-£398.00	-£5,111.00	-£278.00
Wood yield +50%	-£3,693.00	-£201.00	£3,485.00	£189.00	-£3,398.00	-£185.00
Wood yield -50%	-£3,693.00	-£201.00	-£7,144.00	-£388.00	-£5,111.00	-£278.00

Sensitivity to changes in fuelwood and sawlog price

Changes in investment values as a result of a 50% increase and decrease in the price of fuelwood and sawlog on NPV and AEV are presented in Table 8. The result shows that the performance of forestry option relative to the agroforestry and livestock options was most sensitive to changes in wood price thereby substantially altering the ranking of the investment options. Forestry became the most preferred option. Engagement in either livestock or agroforestry options would result in a financial loss.

For instance, at the baseline discount rate, a 50% increase in the price of fuelwood and sawlog increased the NPV of forestry option from -£1,829.00/hectare to £3,668.00/hectare, while NPV of agroforestry option, though negative, increased from -£4,255.00/hectare to -£3,398.00/hectare (Table 8). The NPV and AEV of livestock option remained constant in this analysis.

On the other hand, a 50% reduction in the price of fuelwood and sawlog significantly altered the relative economic viability of the investment options by reducing the NPV of forestry option from -£1,829.00/hectare to -£7,327.00/hectare and the NPV of agroforestry from -£4,255.00/hectare to -£5,111.00/hectare thereby rendering both forestry and agroforestry options economically unattractive (Table 8).

Sensitivity to changes in fuelwood and sawlog yield

A sensitivity analysis was also conducted to determine the effect of a 50% increase and decrease in fuelwood and sawlog yield on NPV and AEV. The result shows that the performance of forestry option relative to the agroforestry and livestock options was most sensitive to changes in wood yield thereby substantially altering the ranking of the investment options. Forestry remained the most preferred option followed by agroforestry while the NPV and AEV for livestock option remained constant in this analysis (Table 8). For instance, a 50% increase in the of yield of fuelwood and sawlog increased the NPV of forestry option from -£1,829.00/hectare to £3,485.00/hectare, while NPV of agroforestry option increased from -£4,255.00/hectare to -£3,398.00/hectare (Table 8).

Conversely, a 50% reduction in the yield of fuelwood and sawlog again altered the relative economic viability of the investment options by reducing the NPV of forestry option from -£1,829.00/hectare to -£7,144.00/hectare and the NPV of agroforestry from -£4,255.00/hectare to -£5,111.00/hectare thereby rendering both forestry and agroforestry options economically unattractive (Table 8).

Sensitivity of scenarios to variation in discount rate

The results of sensitivity of net present value (NPV) and annual equivalent value (AEV) per hectare where all management actions were run at 0%, 2%, 5%, and 8% discount rates are presented in Table 9. The results show that the NPV and the AEV values for livestock and agroforestry scenarios are negative at all discount rates (including the baseline discount rate), indicating financial loss. Forestry option also showed negative values at the baseline and higher discount rates but turned positive at lower discount rates (0% and 2%) implying that investment in forestry will be profitable at the lower discount rates. On the other hand, it is also evident that the values of the economic indicators increase with decreasing discount rate (Table 9). For instance, for forestry option, the estimated NPV (£975.00/hectare) is positive at a lower discount rate of 2% compared to the negative NPV (-£1,829.00/hectare) at higher baseline discount rate of 3.5%.

Forestry option remains the preferred and option for showing positive NPV (£7,306.00/hectare) and AEV (£244.00/hectare/year) at 0% compared to livestock and agroforestry options, though forestry option indicated negative NPV and AEV at the baseline discount rate (Table 9).

Table 6: Sensitivity of net present value (NPV, and annual equivalent value (AEV)

per hectare to variation in discount rate (base rate = 3.5%)

Scenario	Discount Rate	NPV	AEV
Livestock	0%	-£5,337.00	-£178.00
	2%	-£4,264.00	-£190.00
	3.5%	-£3,693.00	-£201.00
	5%	-£3,260.00	-£212.00

	8%	-£2,660.00	-£236.00
Forestry	0%	£7,306.00	£244.00
	2%	£975.00	£44.00
	3.5%	-£1,829.00	-£99.00
	5%	-£3,632.00	-£236.00
	8%	-£5,532.00	-£491.00
Agroforestry	0%	-£4,019.00	-134.00
	2%	-£4,240.00	-189.00
	3.5%	-£4,255.00	-£231.00
	5%	-£4,203.00	-273.00
	8%	-£4,019.00	-357.00

Sensitivity to grants/subsidies

The results of the comparative analysis of the relative economics of the livestock, forestry, and agroforestry scenarios presented so far had been based on the exclusion of the grants/subsidies. A sensitivity analysis was therefore conducted to observe the effect of inclusion of the prevailing grants/subsidies to the three scenarios as follows *https://naturalresources.wales/...woodland-creation/support-available-for-new-woodla*.:

- Livestock scenario: Basic Payment Scheme (BPS) subsidy at £210.10/hectare from year 1 to year 30.
- Forestry scenario: a) Welsh Government Glastir New Planting Payment at £3,600/hectare; b) Glastir Woodland Creation Premium at £350/hectare from year 2 to year 12; and c) Glastir Annual Maintenance Payment at £60/hectare from year 2 to year 13.
- Agroforestry scenario: a) Glastir New Planting Payment at £1,600/ hectare; b) Basic Payment Scheme grant at £210.10/hectare from year 1 to year 30; c) Glastir Annual Maintenance Payment at £30/hectare from year 2 to year 6.
- Deductions were made for the area of the trees which were covered by the tree crowns.

Result shows that the addition of grants significantly altered the relative economic viability as livestock, forestry and agroforestry options registered positive NPV and AEV values at the baseline assumptions and are therefore adjudged economically viable as they all met the decision rule criteria for investment acceptance (Table 10). However, at higher discount rates (5% and 8%) livestock options indicated negative values and is therefore unviable while agroforestry remained viabile at 5% but unviable at 8% discount rate.

It is pertinent to note that forestry option indicated positive NPV and AEV values with or without grant at very low discount rates (0% and 2%) and thereby being the only viable option at discount rates that are below the baseline rate even in the absence of grant (Table 10).

Journal of Agricultural Policy
ISSN 2520 -7548 (Online)
Vol 2, Issue No.1, Pp 42 - 66 , 2020
www.carijournals.org

Table 7: Sensitivity of net present value (NPV, annual equivalent value (AEV) per hectare to application of grants at varying discount rate (3.5%)

Scenario	Discount Rate	NPV Without Grant	NPV With Grant	AEV Without Grant	AEV With Grant
Livestock	0%	-£5,337.00	£966.00	-£178.00	£32.00
	2%	-£4,264.00	£442.00	-£190.00	£20.00
	3.5%	-£3,693.00	£171.00	-£201.00	£9.00
	5%	-£3,260.00	-£30.00	-£212.00	-£2.00
	8%	-£2,660.00	-£294.00	-£236.00	-£26.00
Forestry	0%	£7,306.00	£15,826.00	£244.00	£528.00
	2%	£975.00	£8,755.00	£44.00	£391.00
	3.5%	-£1,829.00	£5,477.00	-£99.00	£298.00
	5%	-£3,632.00	£3,257.00	-£236.00	£212.00
	8%	-£5,532.00	£662.00	-£491.00	£59.00
Agroforestry	0%	-£4,019.00	£2,948.00	-134.00	£98.00
	2%	-£4,240.00	£1,473.00	-189.00	£66.00
	3.50%	-£4,255.00	£778.00	-231.00	£42.00
	5%	-£4,203.00	£301.00	-273.00	£20.00
	8%	-£4,019.00	-£268.00	-357.00	-£24.00

DISCUSSION

The modelling assumption that silvopastoral agroforestry system is a more viable economic undertaking compared to pasture and pure forestry systems is rejected in this study. The results of the bioeconomic analysis show that, in the absence of government subsidies, none of the scenarios is viable at the baseline discount rate. With negative NPV and AEV figures, a decision to engage in any of the three investments based on budgeting information available to investors in 2016 and at the baseline discount rate of 3.5% would certainly result in significant losses to the farmer. This is principally due to output prices being significantly lower than the establishment and running costs, to the effect that even when incomes are discounted to the beginning of the investment period, the NPV and AEV figures per hectare remain negative. Forestry option will incur the least loss in NPV and AEV followed by livestock option and agroforestry option in that order.

The results of the sensitivity analysis suggest that the assumptions used in the analysis are sufficiently realistic. However, significant changes in lamb sale price, wood price, and wood yield greatly influenced the economic viability of the three investment options (Table 8). A 50% increase in the price of lamb changed the NPV and AEV of livestock and agroforestry investments from negative to positive figures thereby rendering both options economically profitable at the base line assumptions with livestock as the preferred option. This change in viability and profitability could be explained by the margin between lamb sale prices and establishment and maintenance costs being large enough to overcome the effects of discounting thereby rendering the NPV and AEV positive. On the contrary, a 50% increase in wood price and yield had a mixed influence on the economic viability of forestry and agroforestry. While forestry option became profitable, agroforestry option remained unviable and would likely require a much higher percentage increase in the price or yield of wood to make it profitable. The question as to whether these increases in prices and yield could be realistic remains a mirage especially with the recent political developments in the United Kingdom, especially the decision to leave the European Union. On the other hand, caution should be exercised here as the argument regarding prices could work both ways. Notably, recent devaluation of the pound has increased, for example, the prices of sheep in pound sterling terms.

The viability of the three investment options in this study decreased with increasing discount rates. This result is in line with the general trend observed in economic investments that shows that high discount rates can significantly reduce the NPV value of a long-term investment where the incomes are accrued late in the lifespan of the investment and often increases the NPV of land use investment where incomes are accrued earlier in the lifespan of the investment. For instant, at a lower discount rate of 2% in the bioeconomic model, the forestry option became economically viable, when it was previously unviable at a higher discount rate of 3.5%.

The observed trend can be explained by looking at the formula used to determine the compound interest factor (1.0pn), which explains the relative effect of discount rate and time between expenditure and incomes. In the formula, p is the rate of interest and n is the number of years of the investment. The rate of interest is raised by the power of the number of years of the investment (Williams, 1988). The number of years of the investment raises the discount factor exponentially and at the higher discount rates, the greater the influence of the number of years is on the investment (Williams, 1988). It can be concluded that at higher discount rates, the period between expenditures and incomes must be short for the investment to remain profitable. In forestry where the investment timescale is much longer than other land use investment, the discount rate used in the investment analysis has a significant effect on the profitability of the decision.

The finding in the present study disagrees with the results of other studies (Clason, 1995; Sibbald,1996; McAdam *et al*., 1999a; Thomas and Willis, 2000; Husak and Grado, 2002; Grado and Husak, 2004; Dangerfield and Harwell, 1990) in which silvopastoral agroforestry investments were reported to outperform pure forestry or conventional livestock grazing investments, as well as the popular belief among farmers and landowners that farm forestry is not a viable economic undertaking (Lawrence *et al*., 2010). Specifically, comparing the financial viability of silvopasture system and pasture system, Sibbald (1996) reported that the net present value for ash (*Fraxinus excelsior* L.) growing in silvopastoral system in lowland UK was greater than the net present value for treeless pastures by 15%. McAdam *et al.* (1999a) and Thomas and Willis (2000) also reported that, under a range of commodity prices and agricultural subsidy support scenarios, silvopasture has a net benefit over open grassland ranging from 34% to 181%, and that even with no farm subsidy support, silvopasture was more profitable (by €20 ha^{-1}) than open grassland because of the additional output of timber from silvopastoral systems. Clason, (1995) reported that silvopasture generated a higher internal rate of return than managed timber or open pasture. Husak and Grado (2002) demonstrated that the adoption of silvopasture is not only economically and biologically feasible but is also more financially attractive when compared with the individual production of soybeans, rice, cattle, and pine plantation.

There is a general perception among farmers that investment in silvopastoral agroforestry will generate little or no economic return and will be unsuccessful. However, it can be argued that if grant assistance was high enough to make an investment in agroforestry economically viable some farmers would consider a change of land use from conventional livestock farming to agroforestry.

The bio-economic model constructed for this study was modified to accommodate potential grant incomes. Addition of prevailing government grant schemes improved the economic viability of the three investment options (Table 10). The eligibility of agroforestry systems for BPS within the UK depended on the nature of the woody component in the system. Where the agroforestry component contains more than 50 trees, appropriate allowances are made for the area taken up by trees, as required by regulation, by deducting areas of land where tree cover prevents growth of vegetation suitable for grazing (Defra, 2006b).

This study has established that pasture productivity, and hence livestock carrying capacity, could not remain constant all through the investment period, even though the trees were pruned and thinned periodically. To make the necessary adjustments, therefore, it is assumed that crown area is negligible for the first 10 years. However, between year 11 and year 20, crowns will increase to occupy 30% of the area (viewed from above) resulting in a loss of 30% of Area Payment by year 20. It is also assumed that crown area will remain constant after year 20 as crowns grow at a constant rate.

Despite the proven financial viability (assuming subsidies are available), and many other positive benefits associated with silvopastoral systems, their acceptance have been highly limited (Dagang and Nair, 2003). This is partly because of high initial investment cost, lack of capital or financial incentives for credit-constrained farmers, lack of awareness among farmers and landowners of agroforestry practices (Thomas and Willis, 1997) and absence of technical expertise for establishing and running these systems, delayed return on investment, and complexity of the systems. Other barriers to wider adoption include highly limited research studies on temperate agroforestry and absence of demonstrable economic viability and practical management skills, and lack of effective information dissemination scheme and outreach support and extension projects (Smith *et al*., 2012). Another major impediment to widespread adoption of agroforestry is a lack of cohesive and comprehensive policy support. High limitation on the number of trees to be integrated into agricultural land poses a serious challenge to policy issues concerning forestry and agriculture.

There is a need to provide some form of subsidy to farmers engaged in any of the three land management systems considered in this study. The question is how should that subsidy be applied. Should it be applied on per area basis with the complexity that it entails, or should it be applied on per tree basis, per livestock basis, per millimetre of water infiltrated basis, per tonne of carbon dioxide sequestered, per farm or tree establishment cost, per overhead cost, per labour cost? Payment for the establishment cost would be better because the farmer must pay all the costs upfront and wait for the benefit long-term and so is saddled with cash flow problem. But if the planting is adequately subsidised, cash flow problem is eliminated and what does the farmer do for income subsequently?

CONCLUSION

In conclusion, this research has found that without significant improvement in markets, an investment in livestock, forestry and agroforestry on a 30-year rotation based on 2016 budgeting information and at 3.5% discount rate is unlikely to be economically viable and profitable unless farmers are provided with grant assistance to receive the associated incomes.

The study disclosed that in the absence of government subsidies, none of the scenarios is viable at the baseline discount rate. However, the application of prevailing government grant schemes significantly improved the economic viability of the three investment options. The study therefore stressed the need for farmers to be provided with some form of subsidy to enable them engage in any of the three land management systems considered in this study but wondered how the subsidies should be applied. Furthermore, the study underscored the imperative need for policy makers to improve awareness of the benefits of grant incomes and address farmers' concerns about the economic viability of livestock, forestry and agroforestry investments.

ACKNOWLEDGEMENT

The completion of this research study was made possible with the assistance, encouragement and guidance of the following people and organisations to whom I owe my sincerest gratitude:

Foremost, I owe my deepest gratitude to my supervisors, Dr. James Walmsley and Dr. Mark Rayment, for their sustained guidance, wisdom, thoroughness, support, patience and commitment over the many years of my field research and during the writing up process despite their many other academic commitments. Both supervisors were instrumental in the development of concepts and understanding of silvopastoral agroforestry systems that enabled this study.

I am deeply indebted to the Nigerian Tertiary Education Trust Fund (TETFUND) for sponsoring my PhD research programme in agroforestry under its Academic Staff Training and Development Programme as well as to the Management of Chukwuemeka Odumegwu Ojukwu University (COOU) (Former Anambra State University), Anambra State, Nigeria for granting me the leave to undertake this research programme.

I am also very grateful to other staff and fellow students of the School of Environment, Natural Resources and Geography (SENRGY) at Bangor University who played significant roles during my studies. My special thanks will go to Ian Harris, Mrs. Llinos Hughes, Mark Hughes, and all other staff at the Bangor University research farm at Henfaes (the site of the Silvopastoral National Network Experiment) for providing me with useful information on the management of the research farm and for their support, assistance and patience during my data collection process and laboratory works.

My greatest thanks go to the Farm Woodland Forum for awarding me the Lynton Incoll Memorial Scholarship that enabled me to present some of my PhD research chapters at the 2014 Farm Woodland Forum annual meeting in Devon, UK. I am equally grateful to all the researchers, staff, students and volunteers who have contributed to the huge body of knowledge that has been generated by the various UK's Silvopastoral National Network Experiments.

Last but certainly not least, the encouragement I received from my friends and family was phenomenal, particularly my spouse, Susan Barredo Nworji, and children, for their love, support, understanding, and extreme patience over the period of my PhD research programme.

Finally, I give gratitude to God for giving me enough spirit and strength to surmount the various obstacles encountered in making the completion of my research studies a reality.

References

Bergez, J. E., Etienne, M., & Balandier, P. (1999). ALWAYS: a plot-based silvopastoral system model. *Ecological Modelling, 115*(1), 1-17.

Bullard, S. H., & Straka, T. J. (1998). Basic Concepts in Forest Valuation and Investment Analysis. Preceda. *Inc., Auburn, AL, USA.*

Burgess, P. J. (2011, December). Agroforestry in the UK. Briefing document prepared for the First European Meeting of Agroforestry Paris.

Burton, R., & Wilson, O., (2000). Farmers' resistance to woodland planting in community forests: The influence of social and cultural factors. Occasional Paper. De Montford University, Leicester, UK.

Chase, L. E., Ely, L. O., & Hutjens, M. F. (2006). Major advances in extension education programs in dairy production. *Journal of dairy science*, *89*(4), 1147-1154.

Clason, T.R. (1995). Economic implications of silvipastures on southern pine plantations. *Agroforest. Syst*. 29: 227-238.

Dagang, A. B., & Nair, P. K. R. (2003). Silvopastoral research and adoption in Central America: recent findings and recommendations for future directions. *Agroforestry systems*, *59*(2), 149-155.

Dangerfield, C. W. and Harwell, R. L. (1990). An analysis of a silvopastoral system for the marginal land in the southeast United States. *Agroforestry Systems.* 10: 187-197.

Davies, O., & Kerr, G. (2015). Comparing the costs and revenues of transformation to continuous cover forestry for sitka spruce in Great Britain. *Forests*, *6*(7), 2424-2449.

Defra (2006b). Single Payment Scheme: Handbook and Guidance for England 2006. Department for Environment Food and Rural Affairs and the Rural Payments Agency from Section C: What land can be claimed under the Single Payment Scheme? pages 19 and 20.

Doye, D. G. (2007). *Evaluating Options for Change*. Division of Agricultural Sciences and Natural Resources, Oklahoma State University.

Glastir Woodland Creation. Rules Booklet. Version 2 March 2016. Welsh Government Rural Communities -Rural Development Programme for Wales 2014-2020 https://naturalresources.wales/...woodland-creation/support-available-for-new-woodla

Godsey, L. D. (2008). *Economic budgeting for agroforestry practices*. University of Missouri Center for Agroforestry. www.centerforagroforestry.org/

Godsey, L. D., Mercer, D. E., Grala, R. K., Grado, S. C., & Alavalapati, J. R. (2009). Agroforestry economics and policy. www.centerforagroforestry.org/ www.centerforagroforestry.org/

Grado, S.C. and Husak, A.L., (2004). Economic Analyses of a Sustainable Agroforestry System in the Southeastern United States. In *Valuing Agroforestry Systems* (pp. 39-57). Springer Netherlands.

Graves, A. R., Burgess, P. J., Liagre, F., Terreaux, J. P., Borrel, T., Dupraz, C., ... & Herzog, F. (2011). Farm-SAFE: the process of developing a plot-and farm-scale model of arable, forestry, and silvoarable economics. *Agroforestry systems*, *81*(2), 93-108.

Husak, A. L. & Grado, S. C. (2002). Monetary benefits in a southern silvopastoral system. *Southern Journal of Applied Forestry*. 26(3): 159-164.

Lawrence A., N. Dandy and J. Urquhart (2010) Landowner attitudes to woodland creation and management in the UK. Forest Research, Alice Holt, Farnham. Available at www.forestry.gov.uk/fr/ownerattitudes

McAdam, J.H., Thomas, T.H. and Willis, R.W. (1999a). The economics of agroforestry systems in the UK and their future prospects. *Scottish Forestry,* 53(1): 37-41.

Nworji, M. J. (2017). Physical and Bioeconomic Analysis of Ecosystem Services from a Silvopasture System. PhD thesis, SENRGY, Bangor University, Wales.

Nworji, M. J. (2019). Allometric Equations for Estimating Biomass of Open- Grown Red Alder (*Alnus rubra* Bong) in A Silvopastoral System. *International journal of agriculture & agribusiness*, *2*(2), 35-49.

Osmond, J., & Upton, S. (2012). *Growing Our Woodlands in Wales-the 100,000 Hectare Challenge*. Institute of Welsh Affairs.

Redman, G. (2015). *The John Nix farm management pocketbook.*, 46th edition. Agro Business Consultants Ltd, Leics

SAC 2014. Farm Management Handbook 2015/16 (No. Ed. 36). Scottish Agricultural College, Edinburgh, UK.

Sibbald, A. (1996). Silvopastoral systems on temperate sown pastures, a personal perspective. In: Etienne, M. (ed), Western European silvopastoral systems, INRA, Paris, pp 23-36.

Sibbald, A.R. and Dalziel, A. (2000). Silvopastoral National Network Experiment - Annual Report 1999. *The UK Agroforestry Forum, Newsletter* No 1. pp2-6.

Sibbald, A. R. (2006). Silvopastural agroforestry: a land use for the future. *Scottish Forestry*, *60*(1), 4.

Smith, J., Pearce, B. D., & Wolfe, M. S. (2012). A European perspective for developing modern multifunctional agroforestry systems for sustainable intensification. *Renewable Agriculture and Food Systems*, *27*(04), 323-332.

Soeleman, S., Sa'id, E. G., Daryanto, H. K. S., & Suroso, A. I. (2014). Annual Equivalent Value, Benefit Cost Ratio, and Composite Performance Index as Valuation Appraisal Support of Teakwood Plantation. *Jurnal Manajemen Hutan Tropika*, *20*(1), 58-65.

Teklehaimanot, Z., Jones, M. and Sinclair, F.L., (2002). Tree and livestock productivity in relation to tree planting configuration in a silvopastoral system in North Wales, UK. *Agroforestry Systems*, *56*(1), pp.47-55.

Thomas, T. H., & Willis, R. W. (1997). Linking economics to biophysical agroforestry models. In *Agroforestry Forum (United Kingdom)*.

Thomas, T.H. and Willis, R.W. (2000). The economics of agroforestry in the UK. Forestry Commission Research Bulletin, 122: 107-122.

Treasury, H. M. S. (2003). The green book. *Appraisal and evaluation in central government*.

Williams, M. (1988). Decision-making in forest management. Letchworth, Hertfordshire, England: Research Studies Press.