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Profitability of Willow Biomass Crops Affected by Incentive Programs

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Abstract The economics of willow biomass crops are strongly influenced by yield, production, and harvesting costs and the delivered price for biomass. Under current management practices, willow biomass crops with yields of 12 oven-dried metric tons (odt)ha^{-1} $year^{-1}$ and a delivered price of \$60 odt^{-1} have an internal rate of return (IRR) of about 5.5 %. Yields below 9 odt ha^{-1} $year^{-1}$ have an IRR <0 %. We examined the impact of different incentive programs on the returns from willow biomass crops and the hectares or tons of willow biomass supported across a range of yields. Incentive programs examined included establishment grants (EG), annual payments (AIP), low cost startup loans, and matching payments offered by two existing programs, the Conservation Resource Program (CRP) and more recently the Biomass Crop Assistance Program (BCAP). EGs covering 75 % of the establishment costs provide high returns for growers on medium to high-productivity sites. Stand-alone AIPs with payments of \$124 ha^{-1} $year^{-1}$ paid over 5–15 years had little impact on profitability for growers but were costly for a funding agency. Low-cost loans with an interest rate of 2–4 % are one of the least expensive approaches (\$1.3–6.6 odt^{-1}) and improve profitability for medium- and high-yielding (8–16 odt ha^{-1} $year^{-1}$) sites. A matching payment incentive providing \$50 per odt delivered was the only individual incentive approach that made low-yielding sites (6 odt ha^{-1} $year^{-1}$) profitable but was costly per odt compared to other incentives. Current CRP incentives made willow profitable across all productivity scenarios. The BCAP program generates higher profits for all productivity scenarios but comes at a higher cost. Effective financial incentives need to be well designed and monitored so that the target audience is reached and the intended policy goals are attained.

Keywords Short rotation woody crops · Willow · Economic analysis · Policy · Financial incentives · Subsidies

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Introduction

Economics of Willow Biomass Crops in New York

Short-rotation woody crops (SRWC) like shrub willow (*Salix* spp.) are a potential source of biomass for energy generation and bioproducts in the USA [1, 2] and globally [3]. While projections indicate that willow and other SRWC systems will be an important part of the future biomass supply, only a limited number of hectares have been deployed to date in the USA and Europe. During the past few years, the infrastructure to support the large-scale deployment of willow biomass crops, such as planting stock nurseries and planting and harvesting systems, have been developing in North America [4] with support from state and federal funds and most recently private industry. However, the high upfront establishment costs, risks associated with the production of this new crop, and the uncertainty of biomass markets over multiple rotations create barriers to large-scale deployment. Currently, the returns from willow biomass crops are not high enough to overcome these and other barriers.

The willow biomass cropping system is based on a single planting and multiple harvests using a coppice management system [5]. Growth rates of new willow varieties in New York State exceed 15 oven-dried-tons (odt)ha^{-1} $year^{-1}$ [6]. The crop's perennial nature and low maintenance requirements result in a very positive net energy balance [7, 8] and can have positive impacts on nutrient cycles, hydrology, soil, and wildlife habitat [9–11]. Research and development of willow biomass crops has been occurring since the mid-1970s in Europe and there are now over 20,000 ha established in Sweden, UK, and other countries. In North America, research on willow biomass crops started in the early 1980s but the system has not been widely deployed with less than 1,000 ha in the region [4].

The development of a budget model (EcoWillow)[1] for willow biomass crops has improved the understanding of the costs and returns associated with the crop. Scenarios with yields of 12 odt ha^{-1} year^{-1} and a biomass price of \$60 odt^{-1} at the plant gate provide an internal rate of return (IRR) of 5.5 and 6.2 % for a rotation length of 3 and 4 years, respectively, under New York State conditions (Table 1; see [12] for details). Due to the systems high planting density and the relatively low value of the biomass, the establishment costs for willow biomass crops are comparatively high (>\$3,000 ha^{-1}, Table 1) and are not recovered until 11–13 years after planting. Crop yields and site productivity have an impact on profitability of willow biomass crops. Low-yielding sites (6–8 odt ha^{-1} year^{-1}) are not profitable in the absence of financial incentives even with lower land rental rates that might be expected for low productivity sites (Table 2; adapted from [12]). Even high-yielding sites (12–16 odt ha^{-1} year^{-1}) with payback periods of 13 years make it difficult for capital-constrained growers to establish willow biomass crops, especially with the uncertainties associated with a new crop and market.

As other agricultural and energy crops developed over the last few decades indicate, expansion of the crops would accelerate research funding, technological innovation, infrastructure development, and efforts to reduce costs [13]. For instance, establishment costs fell by 50 % in Sweden within 3 years once a widespread adoption of willow biomass crop systems occurred in the early 1990s [14]. A common tool to stimulate such expansion for government agencies, nongovernmental organizations or the biomass-processing industry is to offer financial incentives to actors along the supply chain.

Incentivizing Willow Biomass Crops

Previous studies have provided an understanding of financial incentives on the economics of willow biomass crops. However, a structured analysis on how different incentive tools such as establishment grants (EG), annual incentive payments (AIP), incentivized startup loans, or biomass price matching would affect the economics of the system is lacking. Tharakan et al. [15] analyzed the financial impact of

[1] The budget model can be downloaded at http://www.esf.edu/willow/.

Table 1 Input and output variables for the willow biomass crop base-case scenario [12]

		Unit
Input variables		
Project size	10	ha
Biomass growth rate	12	odt ha^{-1} year^{-1}
Rotation length	3	years
Biomass price including transportation	60	\$ odt^{-1}
Land costs including tax, lease, and insurance	85	\$ ha year^{-1}
Administration costs	12	\$ ha^{-1} year^{-1}
Planting stock costs	0.12	\$ cutting^{-1}
Planting density	14,300	cuttings ha^{-1}
N fertilizer cost after every harvest	85	\$ ha^{-1} application^{-1}
Transport distance (excluding field roads)	40	km
Stock removal	740	\$ ha^{-1}
Output variables		
Net present value (NPV)[a]	116	\$ ha^{-1}
IRR	5.5 %	%
Average net earning per hectare	101	\$ ha^{-1} year^{-1}
Earnings per oven dry ton	10	\$
Payback period	13	years
Startup costs including land costs	3,097	\$ ha^{-1}
Harvest costs per hectare	587	\$ ha^{-1}
Harvest costs per ton	16.3	\$ odt^{-1}
Transportation costs	5.1	\$ odt^{-1}

Standard farming operation costs are based on current custom rates for central New York State

[a] Assuming a 5 % interest rate

Table 2 Willow biomass crop yield and land rent scenarios in upstate New York

Scenario	Yield odt ha^{-1} year^{-1}	Land rent[a] \$ ha^{-1}	IRR[b] %	Earnings per ha \$ ha^{-1}	Payback period yrs
1	6	25	–	–126	–
2	8	37	–3.8	–42	–
3	10	49	2.7	42	16
4 (Base case)	12	85	5.5	101	13
5	14	120	6.7	135	13
6	16	155	8.6	195	13

[a] The cost of owning or renting land was assumed to vary in proportion to the productivity of the underlying soils. Estimates of the land charge were derived for each estimate of yield as per the base rate used by the New York State Office of Real Property Services and the National Commodity Crop Productivity Index associated with a given yield level

[b] All other variables being equal to the base case depicted in Table 1

incentive programs under New York conditions focusing on establishment grants paid to the grower as well as tax or emission credits awarded to coal plants cofiring with willow. Styles et al. [16] and Heaton et al. [17] (for the UK) included EGs while Mitchell et al. [18] (for the UK) also considered AIP in modeling the economic performance of willow and other crops in the UK. Apart from these model-based studies, analysis of willow biomass crops in Sweden incorporated field data following the implementation of financial incentives. For instance, Helby et al. [14] discussed the outcomes of EGs on grower's establishment practices and field choices while Rosenqvist et al. [19] stressed the importance of custom-designed policy tools for the specific willow grower in order for incentives to be effective. Mola-Yudego and Pelkonen [20] analyzed the impact of incentives on adoption rates of willow biomass crops in Sweden and found that incentives were necessary to promote these systems, but only worked in regions where agricultural land was not scarce. Due to the limited profit margins and to minimize competition with food production, willow biomass crops are often promoted and in fact established on surplus, abandoned, or marginal agricultural land [19]. Opportunity cost calculations therefore have to consider site productivity besides other regional specifics. Only considerable incentives make willow biomass crops competitive on higher yielding sites with other food- or feed-producing agricultural systems if desired (e.g., Styles et al. [16] for Ireland and Sherrington et al. for the UK [21]). Analysis in the USA indicates that SRWC, without any incentives, will not displace current agricultural use of land at farm gate prices below \$55 odt^{-1}. At \$66 odt^{-1}, about 7.3 million ha of cropland and pasture land could be converted to SRWC by 2030 [22]. With the current delivered wood chip price in the Northeastern USA in the \$55–65 odt^{-1} range, the expansion of willow biomass crops is not likely to occur without some sort of financial incentives or dramatic change in the market (see also Clancy et al. [23] for similar conclusions in a specific UK context).

Effective financial incentives need to be well designed and monitored so that the target audience is reached and the intended policy goals are attained. The types of incentives and their associated costs will vary depending on the point in the willow biomass crop supply chain that is being targeted because there are multiple parties are involved (Fig. 1) and they each have different concerns. For instance, two of the most frequently mentioned by potential growers of willow biomass crops are high establishment costs and a long payback period (\$3,097 ha^{-1} and 13 years, respectively, in Table 1). On the other hand, end users are concerned with the high delivered cost of the biomass. Incentivizing a marketable product (e.g., wood chips delivered) with a matching per-ton payment might help address an end-users concern because it lowers the cost. This might be an appealing approach to a sponsor (e.g., government and conservation agencies) because it is relatively easy to manage and does not have to incorporate procedures to deal with risks associated with the production of a new crop. However, this type of incentive might not result in an increased production of willow biomass crops because the perceived and real bottlenecks for growers remain unaddressed.

Two programs have been initiated in the USA to incentivize the establishment of willow biomass crops, namely the Conservation Resource Program (CRP) [22] and more recently the Biomass Crop Assistance Program (BCAP) [25]. Both programs use a range of incentive approaches to promote the establishment of willow biomass crops. However, there has been no study to date that analyzes the overall economic impact of these programs on willow biomass crops and particularly the cost-effectiveness of these types of incentive approaches applied simultaneously.

Using a newly developed willow crop budget model, we examine the economic performance of willow biomass crops grown with a variety of incentives and under a range of site conditions. The objectives of this paper are:

- Analyze the impact of individual incentive approaches including EG, AIP, startup loans, and matching payments programs on the economic performance of willow biomass crops
- Evaluate how site and yield conditions affect the economic impact of incentive programs
- Assess how combining various incentive techniques such as applied in the two current incentive programs (CRP and BCAP), affects the returns from this system and the areas that could be impacted

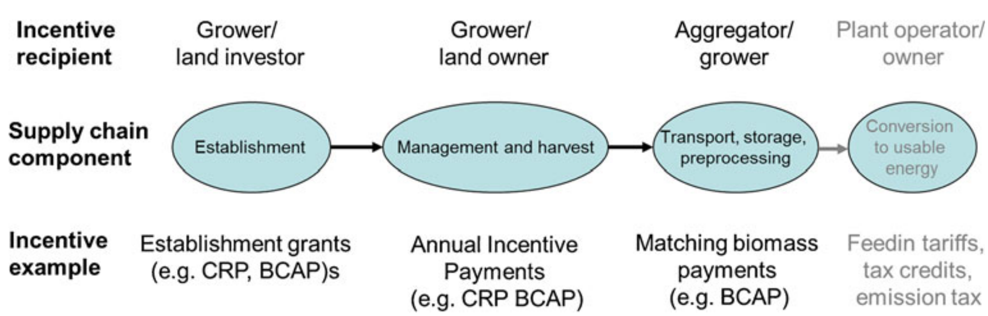

Fig. 1 Potential financial incentive pathways and their recipients along the willow biomass crop system supply chain. The parts of the supply chain in gray font were not analyzed in this study. The CRP and the BCAP are existing US incentive systems

Methods

We used the Microsoft Excel-based crop budget model EcoWillow v1.4 (Beta), which is publicly available online (see footnote 1), to analyze the economic impact of financial incentives on willow biomass crop systems. The base case inputs and the methodological structure of the budget model are described in more detail in [12]. All results are presented before taxes.

For the analysis of the individual incentive approaches, we utilized a net present value framework with a 6 % discount rate to compare various incentive systems over time. To analyze the effectiveness of various incentive systems from the viewpoint of a sponsor organization, we assumed that a hypothetical amount of $1,000,000 would be available to spend (1) immediately (e.g., through establishment grants or loans with annual repayments) or (2) over time as payments occur (e.g., AIPs or match incentives). In the latter case, the unspent funds (assessed each year) would be accruing interest at a rate of 6 %. The following incentives were analyzed across production scenarios ranging from 6 to 16 odt ha^{-1} year^{-1}:

- EG covering 50, 75, and 100 % of total establishment costs prior to the first harvest
- AIP of $124 ha^{-1} year^{-1} paid over 5, 10, or 15 years
- Startup loans covering total establishment costs prior to the first harvest and provided at a 2 and 4 % interest rate. Annual loan payments occur over a 10-year period
- Matching biomass payments providing funds of $25 and $50 odt^{-1} to the producer when biomass is delivered to the end user. Matching payments are available for each of the seven 3-year harvests over the 22 year life of the crop
- The CRP providing an AIP of $124–136 ha^{-1} year^{-1} over 10 or 20 years with an EG of 50 %
- The BCAP providing an EG of 75 %, AIP of $124 ha^{-1} year^{-1} and a matching payment of $50 per odt delivered[2]

Results and Discussion

Impact of Individual Incentive Approaches

Establishment Grants

Startup costs from establishment to the first harvest in year 4 for a base case willow biomass crop system in upstate New York are $3,097 ha^{-1}, and include establishment costs ($2,709 ha^{-1}), land rental ($340 ha^{-1}), and administration costs ($48 ha^{-1}).An EG of 50–100 % of the establishment costs improves the IRR of sites with yields >10 odt ha^{-1} year^{-1}, but fails to create a positive return for very low-yielding (6 odt ha^{-1} year^{-1}) sites (Table 3). If the objective of the program is to make use of marginal, low-yielding agricultural land, then an EG without limitations may not have the desired effect. However, if the marginal land in question is not currently generating a product to help cover fixed costs, like taxes, then it may prompt landowners to engage in this program. Other social factors such as a desire to see abandoned “land in production” will play a role in landowner’s decisions.

Annual Incentive Payments

An AIP program that pays $124 ha^{-1} year^{-1} to growers over a period of 5, 10, or 15 years[3] improves profits of willow biomass crops similar to an increase in yields of about 2 odt ha^{-1} year^{-1}. Provision of an AIP can make medium-ranged productivity-scenarios profitable (10–12 odt ha^{-1} year^{-1}) while scenarios with yields less than 10 odt ha^{-1} year^{-1} remain unprofitable with a 5-year payment period and are only marginally profitable with 10- or 15-year payments (Table 4). While an increase in the payment duration from 5 to 10 years increases the IRR by 11–28 %, the increase in the IRR is smaller (6–11 %) when the payment period is increased from 10 to 15 years. From a sponsor’s perspective, AIP supports a relatively small crop area and amount of willow biomass. Similar to EG, AIP that do not require successful crop establishment have the potential to promote poor crop management in terms of weed and nutrient management, which can result in lower yields and fewer tons of willow biomass being produced.

Startup Loans

While the 6 and 8 odt ha^{-1} year^{-1} productivity scenarios return a negative IRR in either low-interest loan program, all other productivity scenarios are highly profitable in terms of the IRR (Table 5). From a sponsor’s perspective, provision of incentivized loans generally results in large quantities of biomass produced compared with other incentive approaches while providing investors with a reasonable IRR across all medium to high productivity scenarios. An incentivized loan might be less attractive for small-scale growers as earnings per hectare remain low across all productivity scenarios.

[2] BCAP matching payments are up to $45 short ton^{-1} which translates to $50 metric ton^{-1}.

[3] $124 ha^{-1} year^{-1} corresponds to $50 acre^{-1} year^{-1}, which is a common AIP paid to growers for a range of crops in the Northeast under existing USDA programs.

Table 3 Changes in IRR, earning per hectare and payback period for EG covering 50, 75, or 100 % of the establishment costs

EG in % of establishment costs	Output variable	Productivity scenarios (odt ha^{-1} year^{-1})*					
		6	8	10	12	14	16
50 %	Area incentivized (ha)	782	782	782	782	782	782
	Biomass incentivized (odt)	98,570	131,427	164,284	197,140	229,997	262,854
	Incentives per ton ($ odt^{-1})	10.1	7.6	6.1	5.1	4.3	3.8
	IRR (%)	–	2.8	10.0	13.0	14.1	16.2
	Earnings per ha ($ ha^{-1})	−64	20	104	163	197	257
	Payback period (years)	–	16	10	7	7	7
75 %	Area incentivized (ha)	521	521	521	521	521	521
	Biomass incentivized (odt)	65,697	87,596	109,495	131,394	153,294	175,193
	Incentives per ton ($ odt^{-1})	15.2	11.4	9.1	7.6	6.5	5.7
	IRR (%)	–	10.3	18.8	21.8	22.4	24.4
	Earnings per ha ($ ha^{-1})	−33	51	135	193	228	288
	Payback period (years)	–	9	7	7	7	7
100 %	Area incentivized (ha)	391	391	391	391	391	391
	Biomass incentivized (odt)	49,303	65,738	82,172	98,606	115,041	131,475
	Incentives per ton ($ odt^{-1})	20.3	15.2	12.2	10.1	8.7	7.6
	IRR (%)	1.7	47.7	59.7	52.9	47.2	45.9
	Earnings per ha ($ ha^{-1})	−2	81	165	224	259	318
	Payback period (years)	7	4	4	4	4	4

Land area and tons of biomass incentivized refers to a hypothetical $1,000,000 fund available for EGs

(–) A negative IRR or a payback period of more than 21 years

[a] See Table 2 for a definition of the productivity scenarios

Matching Payments

Matching payments of $25 odt^{-1} generate favorable profits for all scenarios except the lowest yielding sites (6 odt^{-1} ha^{-1} year^{-1}; Table 6). With a $50 odt^{-1} matching payment, all yield scenarios become profitable with an IRR ranging from 7.5 % for the lowest yield scenario to 26.2 % for the highest.

A question that remains for these types of payments is how they are made and who in the supply chain benefits from the match. In our analysis, we have assumed the match would be provided to the grower of the crop. Alternatively, matching funds could be provided to processing facilities purchasing biomass to make it competitive with other feedstocks such as coal. If the match provided was $50 odt^{-1} and half of this was realized by the grower, then the $25 odt^{-1} scenario would represent the potential impact on the grower. It should be noted that at a $60 odt^{-1} delivered biomass price ($3.87 GJ^{-1}), a match of $7 odt^{-1} paid to the power plant would match November 2010 delivered coal prices in New York ($3.58 GJ^{-1})[4] [28].

[4] This average coal price at a New York plant gate translates to $84.8 odt^{-1} assuming a lower heating value (LHV) of 23.7 GJ ton^{-1} for coal [29]. We used a LHV of 15.6 GJ odt^{-1} for willow chips and a decreased conversion efficiency of the power plant by 0.53 % when co-firing willow biomass with coal at a 1:9 ratio [8].

Comparative Analysis of Incentive Approaches

Site Productivity

The incentive programs discussed will have different impacts from a grower's or investor's perspective. The improvement in IRR for medium- and high-productivity scenarios when adding an EG financing 50 % of the establishment cost is similar to all three of the AIP approaches. However, only a 100 % EG can make lowest-productivity scenarios profitable. Matching payments of $25 and $50 odt^{-1} provide similar payback periods and IRRs as the 50 and 75 % EG. However, the matching payment approach yields higher earnings per hectare than the EG approach. Neither the AIP nor the matching payment incentive programs analyzed make low-productivity sites profitable. From an IRR perspective, a loan is superior to the AIP in terms of improving the IRR of the system, but the AIP outperforms a loan in terms of average earnings per hectare. The matching payment approach outperforms the AIP in IRR average earnings per hectare and payback period.

All the incentive programs, except the matching payment program, have a linear relationship between site productivity and tons of biomass incentivized across the productivity

Table 4 Changes in IRR, earnings per ha and payback period for annual incentive payments (AIP) of $124 ha^{-1} year^{-1} paid for 5, 10, or 15 years

AIP payments (years; $124 year^{-1})	Output variable	Productivity scenarios (odt ha^{-1} year^{-1})[a]					
		6	8	10	12	14	16
5	Area incentivized (ha)	1,818	1,818	1,818	1,818	1,818	1,818
	Biomass incentivized (odt)	229,119	305,492	381,866	458,239	534,612	610,985
	Incentives per ton ($ odt^{-1})	4.4	3.3	2.6	2.2	1.9	1.6
	IRR (%)	–	−1.4	5.0	7.7	8.9	10.8
	Earnings per ha ($ ha^{-1})	−97	−13	70	129	164	223
	Payback period (years)	–	–	13	10	10	10
10	Area incentivized (ha)	1,049	1,049	1,049	1,049	1,049	1,049
	Biomass incentivized (odt)	132,141	176,188	220,235	264,281	308,328	352,375
	Incentives per ton ($ odt^{-1})	7.6	5.7	4.5	3.8	3.2	2.8
	IRR (%)	–	1.4	6.9	9.4	10.4	12.2
	Earnings per ha ($ ha^{-1})	−69	15	99	157	192	252
	Payback period (years)	–	16	9	10	10	7
15	Area incentivized (ha)	800	800	800	800	800	800
	Biomass incentivized (odt)	100,822	134,429	168,036	201,644	235,251	268,858
	Incentives per ton ($ odt^{-1})	9.9	7.4	6.0	5.0	4.3	3.7
	IRR (%)	–	3.6	8.2	10.4	11.3	12.9
	Earnings per ha ($/ha)	−41	43	127	186	220	280
	Payback period (years)	–	13	9	10	10	7

Area and tons of biomass incentivized refers to a hypothetical $1,000,000 fund available for AIPs

(–) A negative IRR or a payback period of more than 21 years

[a] See Table 2 for a definition of the productivity scenarios

range analyzed (6–16 odt ha^{-1} year^{-1}). Providing incentives using the EG, AIP, or loan programs will cost about twice as much per ton from a sponsor's perspective if the average site productivity of the incentivized crop systems is halved. For example, a $1,000,000 investment in a 15-year AIP for crops with a 16 odt ha^{-1} yield will incentivize 268,858 odt

Table 5 Financial impact of low-interest loan programs providing 100 % of the funds required to establish willow biomass crops

Loan interest	Output variable	Productivity scenarios (odt ha^{-1} year^{-1})*					
		6	8	10	12	14	16
2 %	Area incentivized (ha)	1,198	1,198	1,198	1,198	1,198	1,198
	Biomass incentivized (odt)	151,007	201,343	251,679	302,015	352,351	402,687
	Incentives per ton ($ odt^{-1})	6.6	5.0	4.0	3.3	2.8	2.5
	IRR (%)	–	−3.0	12.9	18.2	18.9	21.4
	Earnings per ha ($ ha^{-1})	−155	−71	13	72	106	166
	Payback period (years)	–	–	19	13	9	7
4 %	Area incentivized (ha)	2,207	2,207	2,207	2,207	2,207	2,207
	Biomass incentivized (odt)	278,020	370,694	463,367	556,041	648,714	741,388
	Incentives per ton ($ odt^{-1})	3.6	2.7	2.2	1.8	1.5	1.3
	IRR (%)	–	−4.7	10.7	16.4	17.5	20.2
	Earnings per ha ($ ha^{-1})	−147	−63	21	80	114	174
	Payback period (years)	–	–	13	13	9	7

Area and tons of biomass incentivized refers to a hypothetical $1,000,000 fund available for low-interest loans

(–) Negative IRR or a payback period of more than 21 years

[a] See Table 2 for a definition of the productivity scenarios

Table 6 Financial impact when providing matching payment grants of $25 and 50 odt^{-1} of biomass delivered from willow biomass crops

Match ($ odt^{-1})	Output variable	Productivity scenarios (odt ha^{-1} year^{-1})[a]					
		6	8	10	12	14	16
25	Area incentivized (ha)	663	497	398	332	284	249
	Biomass incentivized (odt)	83,539	83,539	83,539	83,539	83,539	83,539
	Incentives per ton ($ odt^{-1})	12.0	12.0	12.0	12.0	12.0	12.0
	IRR (%)	0.5	7.2	11.9	14.6	16.4	18.5
	Earnings per ha ($ ha^{-1})	6	134	262	365	443	547
	Payback period (years)	19	13	10	7	7	7
50	Area incentivized (ha)	332	249	199	166	142	124
	Biomass incentivized (odt)	41,769	41,769	41,769	41,769	41,769	41,769
	Incentives per ton ($ odt^{-1})	23.9	23.9	23.9	23.9	23.9	23.9
	IRR (%)	7.5	13.6	18.4	21.5	23.7	26.2
	Earnings per ha ($ ha^{-1})	138	310	481	628	750	898
	Payback period (years)	13	7	7	7	7	7

Area and tons of biomass incentivized refers to a hypothetical $1,000,000 fund available for matching grants

(–) Negative IRR or a payback period of more than 21 years

[a] See Table 2 for a definition of the productivity scenarios

of biomass but on a site that yields only 8 odt ha^{-1} only 134,429 odt will be incentivized with the same funds.

Risk of Crop Failure and Project Abandonment

Besides increasing profitability, the incentive programs discussed also attempt to reduce investment risks to growers and sponsors. For instance, while site quality is a factor in the long-term production of willow biomass crops, successful establishment is a key factor because of the perennial nature of the system. To maximize the impact of all incentive programs and reduce the risk of production failure, successful establishment of the crop needs to be ensured. EGs providing 100 % of establishment costs upfront run the risk of resulting in poorly established crops and questionable site selection [14].[5] Experiences in Sweden with 100 % EGs showed that there were many areas where the crop was unproductive, which negatively influenced the opinion of other landowners about willow biomass crops. Thus, instead of creating a self-sustaining and growing industry, the termination of the incentive programs resulted in a rapid decline in the rate of establishment of new willow biomass crops in the mid-1990s [14]. A performance-based EG approach has been adopted in the UK's Energy Crops Scheme where first-year crop survival rates have to be >80 % before reimbursement claims are processed [26].

Incentivized loans might be more interesting to larger growers and investment entities whose focus is to maximize profits and who are interested in debt leverage and/or have access to larger land areas to spread out their investments. An incentivized loan might be less attractive for small-scale growers as earnings per hectare remain low across all productivity scenarios.

Some risk measures are mutually beneficial to growers and grant sponsors alike such as ensuring proper establishment. However, some forms of risks are mutually exclusive by both groups. From a grower's perspective, an EG reduces financial risk by minimizing payback time (Table 7), which is often cited as a concern with perennial energy crops like willow [27]. This could lead to an early project termination if better opportunities for a grower arise, which in turn increases the risk of a grant sponsor to miss long-term production goals. This risk is often mitigated by imposing penalties for early withdrawal from these programs [30]. Other incentives are less complex in their risk mitigation. For instance, a matching payment decreases the risk to a grant sponsor of failed production goals while it also reduces the risk to a grower of unattractive biomass prices. Moreover, our calculations assume that back-loaded incentive programs such as matching payment program are available for the entire life of the crop that is being established. This bears considerable risk for growers who commit to the crops in the volatile environment of agricultural policies. Uncertainty of incentive programs over the life of a willow crop is another important risk factor for growers. For example, the volatility of the set aside rate in Europe has been cited as a policy issue that has negatively impacted the expansion of energy crops [27].

[5] Helby et al. [14] state that 30 % of willow biomass crops were established on non-clay soils that are considered unsuitable for this crop. Of the surveyed farmers who received incentive payments, 41 % regretted planting willow or had reduced or terminated their plantation.

Table 7 Ranking of incentive programs for willow biomass crops for various performance measures relevant to grant recipients or donors

	Minimize incentive costs per ton	Minimize payback period	Maximize IRR	Balance yearly income	Maximize return per ha	Maximize area incentivized
Establishment grant	±	++	++	±	+	+
Annual incentive payment	+	+	+	++	+	++
Low-interest loan	++	−	+	−	±	++
Matching payment grant	−	+	+	+	++	±

If feedstock unspecific, it is questionable how a matching payment will stimulate dedicated energy crops like willow that depend on investments and long-term planning to overcome a lag time of 4 or more years to the first harvest. If these matching payment programs are in place for only a short time, there is a limited incentive to establish new energy crops. From a sponsors' perspective, matching payments are costly and only incentivize a relatively small amount of biomass. It is also likely that the additional biomass will only be supplied for as long as the matching payment is in place.

Cash Flow Steadiness and Risk

Another important difference between the incentive programs is the timing and flow of payments. In the critical early years, the AIP provides funds on an annual basis, which farmers and other rural landowners involved in annual cropping systems are accustomed to. AIPs reduce cashflow risks especially for small-scale growers considerably by ensuring a reliable annual income that can cover fixed costs such as property taxes [19].

Matching payments, on the other hand, reinforce the irregular cash flow of willow biomass systems by providing cash flow only every 3–4 years at harvest time. At what price point such a matching payment reaches an acceptable high-risk premium, i.e., the IRR that a willow biomass crop needs to produce eventually to attract interest by growers is highly subjective and difficult to quantify [27]. The EG addresses landowners' concerns about the upfront investment required for willow biomass crops, but does not help with the concern about annual cash flows from the system.

Incentivized loans might be more interesting to larger growers and investment entities whose focus is to long-term maximize profits and who are interested in debt leverage and/or have access to larger land areas to spread out their investments. Steadiness of cashflow plays a reduced role for these incentive recipients.

While reducing some of the financial risks associated with new dedicated energy crops like willow, these programs do not address risks that may impact the long-term viability and production potential of these crops. Due to their perennial nature impacts from severe weather events, pests, or diseases may reduce yields from these systems over long periods of time, which can strongly influence returns. The lack of a well-developed and stable market is another risk that is borne by potential producers of a long-term crop [27]. Since positive returns from these systems occur after the later harvests, the uncertainty of an end user who will pay for this material is an important risk to consider.

Cost-Effectiveness of Incentives

Matching payments of \$25 or \$50 odt^{-1} are the most costly incentives when the metric used is dollars invested per percent increase in IRR (Fig. 2). AIPs are the second most expensive incentive approach based on the dollars invested per point increase in IRR metric. In the scenarios modeled, all AIP approaches result in a similar cost per point increase in IRR. As the AIP payments increase, the IRR also

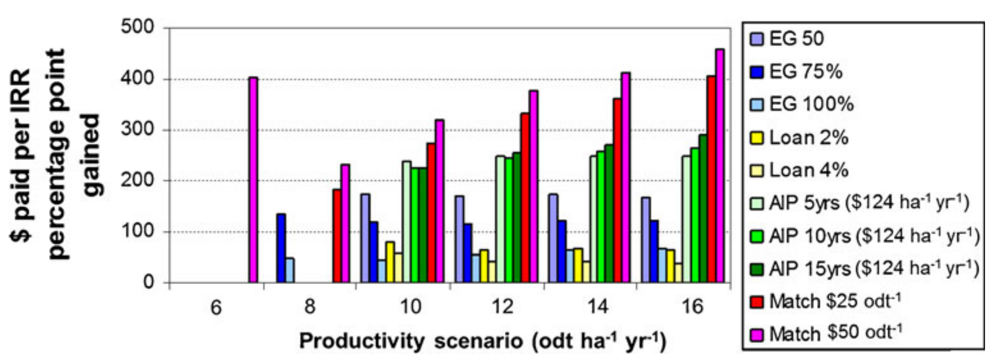

Fig. 2 Costs associated with increasing the IRR by 1 percentage point for different productivity scenarios (see Table 2) through various incentive approaches including EG, AIP, startup loans, or matching biomass payments (match). Only scenarios generating profits (IRR >4 %) after incentives are reported

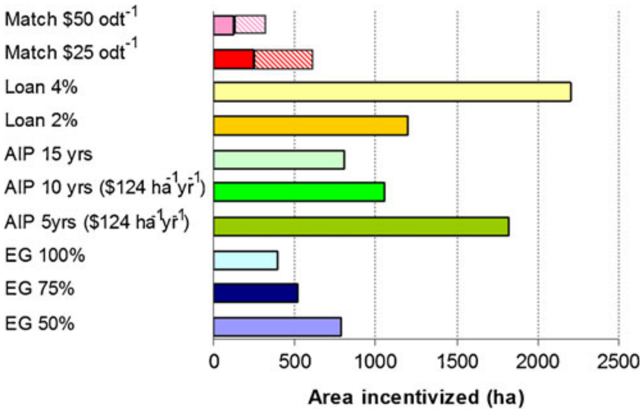

Fig. 3 Land area for willow biomass crops that would be supported by a \$1,000,000 fund through various incentive approaches including EG, AIP, startup loans, or matching biomass payments incentives. In the case of matching biomass payments, the *shaded areas* indicate the area range depending on the productivity scenario (low range for high-productivity scenarios and high range for low-productivity scenarios)

increases in a linear fashion. The EG approaches analyzed are a low- to mid-range cost incentive and resulted in the highest variation in costs among one type of incentive approach. Increasing the EG reduces the cost per IRR percentage point. The loan incentives are the most cost-effective incentive using this metric and are similar in costs across the range of yields. All incentive approaches provide fairly even support in raising IRR across all productivity scenarios, while only matching payments and EGs are able to make low-yielding scenarios profitable under certain conditions.

The impact of the different incentive programs can also be assessed by examining the hectares of willow biomass crops that would be supported. The only program where the area impacted varies depending on the yield of the crop is the matching payment program (Fig. 3) because the other incentive programs are based on land area. The area impacted by the matching payment program decreases from 663 to 124 ha per \$1,000,000 invested as the yield increases. The EG program impacts the next smallest land area, ranging from 391 ha for the 100 % EG program to 782 ha for the EG 50 % program. The 75 % EG program, similar to what is proposed in the BCAP program, would incentivize just over 500 ha per \$1,000,000 invested. As the length of the AIP increases, the number of hectares that will be impacted decreases from 1,818 to 800 ha. The 4 % loan program would impact the greatest land area at 2,207 ha while the 2 % program would impact the second largest area at 1,198 ha. The total biomass incentivized (Fig. 4) has an inverse relationship with the program costs to increase the IRR of the system (Fig. 2).

Another way to assess the impact of the inventive programs is to determine the number of delivered tons of willow biomass that would be provided for a \$1,000,000 invested in different incentive programs (Fig. 4). The matching payments programs support the smallest number of tons of willow biomass at just under 84,000 for the \$25 odt^{-1} level. The yield of the crop does not have an impact on the tons of biomass supported. In contrast all the other incentive programs support more tons of biomass per \$1,000,000 as the yield of the crop increases. The 4 % loan program supports the largest number of tons ranging from 463,000 odt at the 10 odt ha^{-1} year^{-1} yield to over 741,000 odt at the 16 odt ha^{-1} year^{-1} yield level. The 5-year AIP supported the next largest area ranging from 382,000 to 611,000 odt across the range of yields. The number of tons supported by the remaining programs decreased in the following order 2 % loan>AIP 10 years>AIP 15 years>EG 50 %>EG 75 %>EG 100 %.

The Economic Impact of Two Existing Incentive Programs

The Conservation Resource Program

Willow biomass crops are qualified to receive financial support under the conservation reserve program in New York [24]. This program provides an establishment grant that covers 50 % of costs and an AIP of around \$124–136 ha^{-1} (Green, V, United States Department of Agriculture, personal communication, July 2009).

The CRP program can improve profitability of willow biomass crops especially for low-productivity sites (Fig. 5).

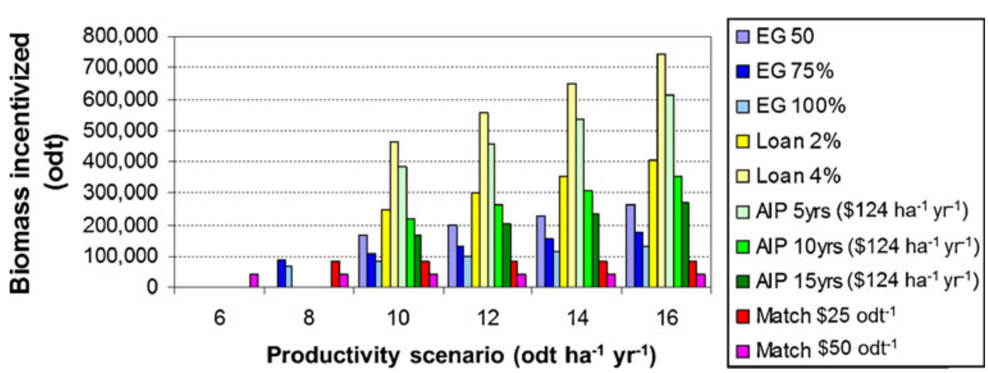

Fig. 4 Number of tons supported for various productivity scenarios (see Table 2) under different incentive approaches including EG, AIP, startup loans, or biomass match incentives. Only scenarios generating profits (IRR >4 %) after incentives are reported

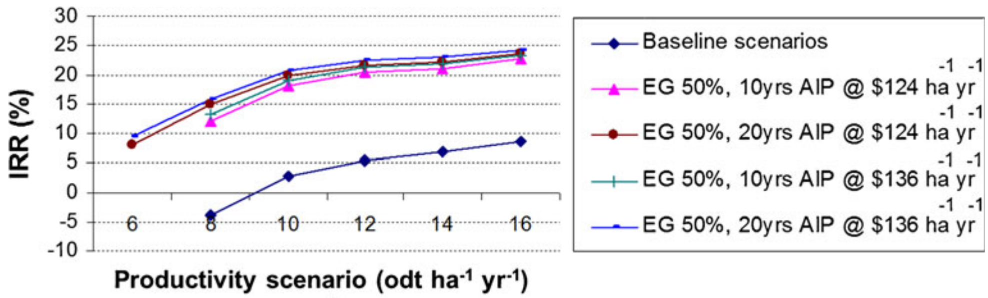

Fig. 5 Internal rate of return for willow biomass crops under various productivity scenarios with CRP incentives including EG and AIP across a range of productivity scenarios (see Table 2)

An AIP of \$136 ha^{-1} year^{-1} over 20 years combined with a 50 % EG would make a willow biomass crop yielding 6 odt ha^{-1} year^{-1} profitable with an IRR of 9.3 % (Fig. 5). However, for all other productivity scenarios the length and amount of the AIP had little effect on the IRR for medium- to high-productivity scenarios. While the EG of 50 % of establishment costs raises the IRR by around 6.5–7.5 percentage points, an AIP paid over 5 years rises the IRR by 5 percentage points across all productivity scenarios. As an EG is considerably more cost-effective from a sponsor's perspective than an AIP, future programs might want to focus more resources on EGs while keeping low- and short-term AIPs in place. The exception to this would be low-productivity areas.

Biomass Crop Assistance Program

The BCAP established in 2008 is administered through United States Department of Agriculture. As of August 2010, more than \$243 million across the USA and over \$7.7 million in New York State had been spent on the collection, harvest, storage, and transportation (CHST) matching payment portion of this program [31]. The CHST pays a matching \$1 for each \$1 the producer receives per ton of delivered biomass (measured on an oven-dry basis and capped at \$49.6 odt^{-1}). The biomass crop establishment portion of the program provides an eligible producer reimbursement for up to 75 % of the establishment costs and an AIP for up to 15 years for woody crops, with reductions in each of the years when harvests occur [32].

Combining all the components of the BCAP program, EG, AIP for 15 years for woody crops and matching payments result in very high IRRs across all productivity scenarios (Fig. 6) ranging from an IRR of 43–64 %. When only a single BCAP incentive payment is in place (i.e., either EG, AIP, or CHST match) only the EG and CHST match provide reasonable returns in the lower productivity scenarios. However, while both incentive approaches have similar results, the increased profitability through the CHST match providing \$50 odt^{-1} comes with a considerable higher cost per ton than the EG providing 75 % of the establishment costs (Fig. 2, Table 6). A combination of an EG of 75 % with the AIP provides favorable returns of 14–33 % across the range of yields studied.

Conclusions

Willow biomass crops on sites in New York State with yields <9 odt ha^{-1} year^{-1} are currently unprofitable in the absence of incentive programs. Incentive programs such as EG, AIP, incentivized startup loans, or matching payment programs are being considered to encourage growers to establish willow crops in larger quantities. We analyzed the impact of these individual incentive approaches as well as two existing incentive programs on the profitability of the willow crops in terms of their cost effectiveness from a sponsor's perspective, performance across a range of productivity of sites, and their attractiveness in the minds of specific categories of growers.

Proper establishment and maintenance of willow biomass crops under any of these incentive programs is essential. Simply investing large amounts of incentives while not ensuring that the crops are well established and maintained—so reasonable yields are generated—will result in dollars being wasted and a probable delay in large-scale deployment of the system. Even 100 % EGs cannot make the lowest yielding sites (<6 odt ha^{-1} year^{-1}) profitable, but do provide high returns (>47 %) on sites with >8 odt ha^{-1} year^{-1}. From a sponsor's perspective, EGs are fairly expensive compared to AIPs. Despite their fairly high costs per ton of biomass, AIPs

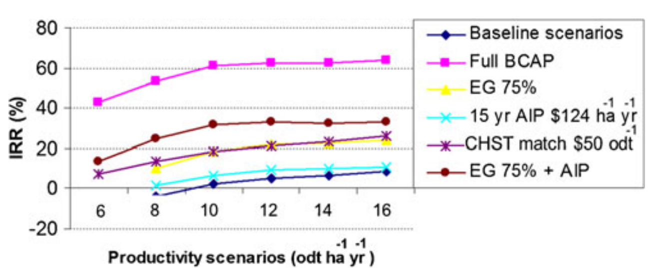

Fig. 6 Internal rate of return for willow biomass crops with various combinations of incentives included in the BCAP comprising EG, AIP, or CHST matching payments under various productivity scenarios (see Table 2)

are unlikely to make low-yielding sites profitable, but they can provide regular annual income, which can be a crucial economic variable to growers. Providing AIPs beyond 10 years after establishment does not improve profitability to any appreciable extent. Loan programs can be a cost-effective way to improve the profitability of medium and high-yielding sites. Depending on given annual income per hectare, they might especially attract investors and large-scale growers and not be suitable for small-scale owners. A match program providing \$50 odt^{-1} of delivered biomass, is the only incentive that can make low-yielding sites (~6 odt ha^{-1} $year^{-1}$) profitable in the absence of other incentive programs. At the same time, the match programs analyzed (\$25 odt^{-1} and \$50 odt^{-1}) are the most expensive incentive approaches evaluated and do not contribute to overcoming the investment hurdle during crop establishment.

The incentive approaches analyzed each have their own strengths and weaknesses. Deciding which factors are strengths and which are weaknesses will to some extent depend on the players involved in the willow biomass crop supply chain (Table 7). Balancing these perspectives will be important in developing an effective incentive system that launches a new crop like willow biomass. From a grower's perspective, the EGs are appealing because they address concerns with upfront costs and increase the IRR. They are not as effective at addressing the annual cash flow concern that is often expressed by smaller growers. From a sponsor's perspective, the establishment grants are costly on a per ton of biomass basis and have the potential risk to disrupt the development of the industry if they are not managed properly. The loan options are the most cost effective from a sponsor's point of view, but they do little to address growers concerns about payback period and an annual cash flow. Balancing these various perspectives will be important in developing an effective incentive system that launches a new crop like willow biomass.

Our results support the notion of Rosenqvist et al. [19] that it is "important for policy makers and actors in the bioenergy business to have sound knowledge of willow growers to effectively design information campaigns and marketing strategies." For instance, while providing incentivized startup loans to growers might be one of the most cost-effective measures from a sponsor's perspective and attractive from an investor's perspective, this kind of incentive also results in very low earnings per hectare, which may make this kind of incentive undesirable, especially for small-scale growers. It is important to realize that large capital investments are one of the major hurdles for establishment of willow biomass crops especially for small-scale growers. Nevertheless, it needs to be kept in mind that a grower's choice for a certain crop is not only influenced by expected net income but also the crops' growing characteristics such as the commitment period to the crop or the need for specialized planting and harvesting machinery [33].

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